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METHODOLOGY INVESTIGATION

FINAL REPORT

CHAMBER VERSUS ENVIRONMENTAL DETERIORATION TESTS

by

William A. Dement
US Army Tropic Test Center

Oscar H. Calderon
US Army White Sands Missile Range

January 1979

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UNITED STATES ARMY TROPIC TEST CENTER

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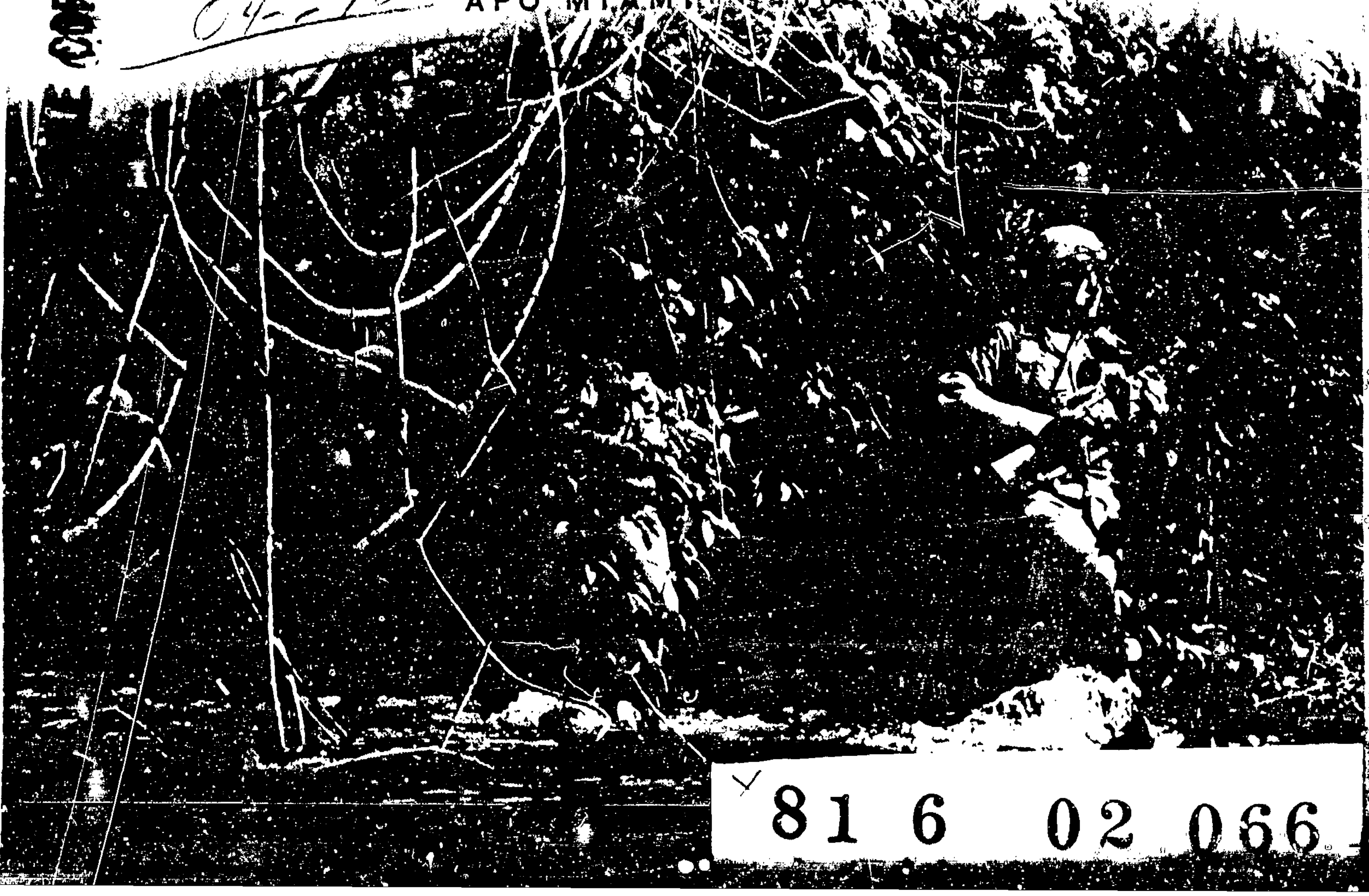

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The US Army Tropic Test Center, and the US Army Materiel Test and Evaluation Directorate, White Sands Missile Range, conducted a 1-year methodology investigation to determine correlations between test results obtained for selected systems exposed to the humid tropics and in controlled environmental test chambers. A tropical greenhouse was evaluated as an alternative to standard temperature-humidity chambers.

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It was concluded that the tropical greenhouse exposure provided a more accurate prediction of tropic performance than the temperature-humidity chamber. Acceleration of tropic degradation processes was not observed in simulated environments. At least 6 to 12 months were required to produce failure.

It was recommended that further studies be conducted to refine and validate the tropical greenhouse methodology in order to better predict materiel performance in the humid tropics. This refinement and validation is required prior to substituting the greenhouse methodology for field exposure testing. Because degradation processes are not accelerated in the chamber, a cost comparison study should be conducted between chamber testing and field testing in the humid tropics.

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FOREWORD

This acknowledges the cooperation and assistance of David M. Malseed, Electronics Engineer, Dr. James F. Sprouse, Chemist, Dr. Dean Neptune, Biologist, George F. Downs and Eldon M. Cady Jr., Materials Engineers from US Army Tropic Test Center (USATTC); and Walter Gregory, Electronics Technician, and Geoffrey Whitney, Electronics Engineer, from the Army Materiel Test and Evaluation Directorate (ARMTE). The study was conducted under the technical supervision of Dr. D. A. Dobbins, Chief, Technical Division, USATTC.

SECTION 1. SUMMARY

1.1 BACKGROUND

Attempts to correlate data from natural field trials with data from environmental chambers are not new. Many related investigations have been conducted by various agencies including US Army Test and Evaluation Command (TECOM). In February 1974, TECOM chaired an informal meeting at White Sands Missile Range (WSMR), NM, to discuss and review problems related to correlating simulated and natural environmental test results. As a result of this meeting, a coordinated effort was establilshed between US Army Tropic Test Center (USATTC) and Army Materiel Test and Evaluation (ARMTE), WSMR. An investigation was proposed to compare results from chamber testing, i.e., a tropical greenhouse and a fungus chamber, with results obtained from exposures in a natural humid tropic environment. The study was a novel, innovative approach to chamber versus field comparisons in that the tropical greenhouse was designed to simulate many of the environmental factors present in a natural humid tropic environment.

The study would be considered successful if procedures could be established for chamber simulation of tropic environmental effects on materiel performance. TECOM funded the joint proposal. Investigations were started by USATTC in January 1976, and by ARMTE in March 1976. This final report includes comparisons of results from the USATTC and the ARMTE investigations.

1.2 OBJECTIVE

The objective of this investigation was to determine the levels of correlations that may exist between test results obtained from selected systems exposed in the humid tropics and in controlled environmental test chambers.

1.3 SUMMARY OF PROCEDURES

Two different types of test items were designed and fabricated by USATTC to perform known measurable functions. Digital electronic and optical systems were combined into one test item and a pneumatic/hydraulic/mechanical system (PHM) was designed into a second test item. Detailed test procedures and failure criteria were established for each test item to assure comparability of data obtained. Some of the test items were established as controls and maintained in air-conditioned laboratory environments at WSMR and USATTC. The remaining test items were placed at ARMTE in a simulated tropical greenhouse and in a fungus chamber, and at USATTC in open and jungle exposure sites. Exposure of the optical and electronic systems began in January 1976 at USATTC and in May 1976 at ARMTE. The PHM test items were placed in the ARMTE greenhouse and fungus chamber in September 1976 when the simulated rainy season was started, because USATTC PHM test exposures began at the beginning of the rainy season, March 1976.

	Test Item Exposure Periods																
	1976												1977				
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Optical-Electronic System																	
USATTC	X	X	X	X	X	X	X	X	X	X	X	X	X				
WSMR					X	X	X	X	X	X	X	X	X	X	X	X	X
PHM System																	
USATTC			X	X	X	X	X	X	X	X	X						
WSMR									X	X	X	X	X	X	X	X	X

Visual examinations and functional checkouts were performed on all test items at approximately 15-day intervals for the duration of the test. Test item degradation was measured in terms of changes in performance and system/component failure rates. A component was classified as susceptible to degradation in an exposure environment if more than one failure or reduction in performance occurred in that environment during the course of the study. ARMTE terminated its greenhouse and fungus chamber exposures in May 1977 and shipped all the test items to USATTC for a joint final evaluation by both ARMTE and USATTC personnel.

Data from the Canal Zone exposures were used as measures of expected item performance in the humid tropics. Data from the tropical greenhouse and fungus chamber were compared with those from the natural exposures to determine whether the artificial environments caused the same type and degree of materiel degradation as the natural environments. The tropical greenhouse represented a new approach to chamber testing in that a wide variety of factors found in the natural tropic environment were included, i.e., temperature, humidity, rainfall, solar radiation, vegetation, insects, micro-organisms and soil. The fungus chamber represented a conventional temperature-humidity chamber cycled to approximate the humid tropics.

1.4 SUMMARY OF RESULTS

1.4.1 Controls

None of the control test items had any failures or showed any significant change in system performance during the 1-year test.

1.4.2 Optical System

System Failure Rates. Column 2 of table 1 presents the optical system failure rates calculated at the completion of the test. Statistical analysis of the failure data indicated that only the frequency of occurrence of system failure at the USATTC open exposure site was significantly different from that at the USATTC jungle exposure site and the WSMR tropical greenhouse. The frequency of occurrence of system failure at the open exposure site was significantly less than that at the other two exposure sites.

Component Failures and Degradation. Three components were identified as susceptible to deterioration in the test environments: operational amplifiers, light emitting diodes and lenses. However, the occurrence of operational amplifier failures at the USATTC open exposure site was significantly less than that at the other three test environments.

Table 1. Chamber Versus Environmental Deterioration Test Data Summary

Test Environment	Optical System: System Failure Rate (failures/1,000 exposure hours)	Optical System: Cleaned Lenses With Transmissivity Deterioration (percent)	PHM System: System Failure Rate (failures/1,000 exposure hours)	PHM System: Average Percent Change in Piston Displacement (25 psig input pressure)	(40 psig input pressure)	(25 psig return input pressure)
USATTC Jungle Exposure Site	0.16	20	0.068	-70	-67	-83
USATTC Open Exposure Site	0.03	0	0.060	-66	-52	-83
WSMR Greenhouse	0.12	20	0.053	-64	-60	-81
WSMR Fungus Chamber	0.09	0	No Failures	-37	-40	-65

Degradation in lens transmissivity was measured at the completion of the test before and after cleaning of the lenses. The uncleaned lenses at the greenhouse and open exposure sites showed a significant reduction in transmissivity. Reduction of transmissivity was caused by surface deposits of dirt and corrosion products on the lenses. No biological activity was observed. The severity of transmissivity degradation was greater in the greenhouse environment than at the tropic open exposure site. There was some reduction in lens transmissivity in the tropic jungle and the fungus chamber environments; however, it was not significantly different from that at the control site. Column 3 of table 1 presents the percentages of lenses that exhibited significant reduction in transmissivity after the lenses had been cleaned. All other lenses exposed in the four test environments showed no significant reduction in transmissivity after they had been cleaned.

Initial System Failures. The initial component failure in the optical system occurred after 16 weeks in the tropic open exposure site (an operational amplifier), after 17 weeks in the fungus chamber (a resistor), after 17 weeks in the tropical greenhouse (a resistor and an operational amplifier), and after 23 weeks in the tropic jungle exposure site (a resistor).

The three resistors noted above were the only resistor failures that occurred during the entire exposure period. These resistors were probably "weak sisters" from the lot and their short life span (infantile failures in humid-tropic-type environments) should not be considered indicative of the matured reliability of the lot. Neglecting resistor failures, the initial component failure in both the fungus chamber and jungle exposure site was an operational amplifier. The failure occurred after 42 weeks of exposure in the fungus chamber and after 27 weeks of exposure in the jungle site. System failures (neglecting resistor failures) amounting to 20 percent of the systems exposed at a test environment occurred after 27, 27, 24 and 42 weeks of exposure in the jungle and open exposure sites, tropical greenhouse and fungus chamber, respectively.

1.4.3 Digital Electronic System. This system was most insensitive to degradation in all test environments. One system failure occurring during the 12-month exposure period was considered to be a random failure. Illuminance measurements of the digital display exhibited no significant deterioration in any of the test environments.

1.4.4 Pneumatic/Hydraulic/Mechanical (PHM) System

System Failure Rates. Column 4 of table 1 presents the PHM system failure rates calculated at the completion of the test. Statistical analysis of the failure data indicated that there were no significant differences in the numbers of system failures occurring at the four test environments.

Component Failures and Degradation. System performance was measured in terms of PHM piston displacement under three input pressure conditions: piston displacement under an input pressure of 25 pounds per-square-inch gauge (psig), piston displacement under an input pressure of 40 psig and piston displacement following a return to an input pressure of 25 psig from 40 psig. Similar systematic downward trends of the performance data were observed for all test environments. Columns 5, 6 and 7 of table 1 present the average percent change in piston displacement at the completion of the test. As a measure of the association among the performance data degradation trends observed for the four test environments during the period of the study, correlation coefficients between related performance data for the different test environments were computed using estimates of the mean piston displacement at biweekly intervals. Correlation coefficients are presented in table 2. Corrosion of the hydraulic slave cylinder was the major cause of performance degradation and failure in all test environments.

Initial System Failures. The initial failure of the PHM system occurred after 27, 28 and 33 weeks of exposure in the open exposure site, tropical greenhouse and jungle exposure site, respectively. Failures amounting to 20 percent of the systems exposed at a test environment occurred after 33, 34 and 33 weeks of exposure in the open exposure site, tropical greenhouse and jungle exposure site, respectively. There were no system failures in the fungus chamber environment.

Table 2. Correlation Coefficients Between Related PHM System Performance Data for the Four Test Environments.

Test Environments	25 psig Input Pressure	40 psig Input Pressure	25 psig Return Input Pressure
Jungle Versus Greenhouse	0.91	0.96	0.93
Jungle Versus Fungus Chamber	0.78	0.91	0.90
Jungle Versus Open	0.88	0.95	0.90
Open Versus Greenhouse	0.89	0.93	0.80
Open Versus Fungus Chamber	0.79	0.85	0.76
Greenhouse Versus Fungus Chamber	0.87	0.96	0.92

1.5 ANALYSIS

1.5.1 Because no performance degradation or failures were found in the control test items, the changes in performance and failures found in the test environments were attributed to environmental effects rather than inherent properties of the test items. (Note: A test item was not classified as susceptible to environmental degradation if only one failure of the item occurred and if no reduction in performance occurred during the course of the study.)

1.5.2 Comparison of the effects of the test environments on the test items were made in terms of item performance, average failure rates and identifications of susceptible components. Unless otherwise stated, tests of statistical hypotheses were performed at the 0.05 level of significance.

1.5.3 For the optical system, both chamber environments produced effects similar to those observed in the natural environments with the following exceptions: (1) the tropic open exposure site produced significantly fewer failures of operational amplifiers than the chamber environments, and (2) reduction of lens transmissivity during the exposure period was significantly greater in the greenhouse environment than in the natural environments.

The occurrence of operational amplifier failures at the tropic open exposure site was also significantly less than that at the tropic jungle exposure site. The difference in materiel effects at the two natural environments demonstrates the previously reported[1] observation that the onset and severity of degradation to materials and materiel item performance are dependent on the type of humid tropic exposure to which the item is subjected. If different exposure modes in the humid tropics elicit significantly different performance responses from materiel items, then obviously one set of chamber conditions will not provide test results which correlate with those from all possible humid tropic exposure modes. This situation indicates the need for chamber test methodologies to simulate multiple humid tropic environmental exposure modes. The proper selection of chamber test conditions for a particular test item would be dependent on the expected or worst case use and storage conditions for the item. For example, wheeled vehicles that would be expected to be employed most often in an environment similar to the tropic open environment of the study would require a chamber test that simulated a humid tropic open environment rather than a tropic jungle environment.

Reduction in lens transmissivity during the course of the investigation was greatest for the lenses exposed in the greenhouse environment. The lenses of the tropic open exposure site also exhibited significant reduction in lens transmissivity, but the reduction was significantly less than that at the greenhouse environment. Reduction in lens transmissivity was caused by the accumulation on the lenses of dirt and corrosion products from the optical system's housing. Corrosion products were deposited on the lenses primarily through the action of rain penetrating into the test item at the greenhouse and tropic open exposure sites. This was evident from the shapes of the deposits which were in the form of splash marks. Also, several times during the study, accumulation of water was observed in the test items at these sites. The greater transmissivity loss for the greenhouse lenses can be attributed to the more severe corrosion of the housing in the greenhouse environment. Corrosion was promoted by the presence of mineral deposits on the housing surface, the source of which was the tap water used for the humidity control and rain in the greenhouse. It is believed that the use of a more appropriate water source would have resulted in the transmissivity losses being more similar to those recorded at the tropic open exposure site.

The lack of correlation between the levels of lens transmissivity reduction at the tropic open and jungle exposure sites demonstrates another example of the different effects which exposure modes have on materiel items.

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[1]Sprouse, J. F., M. D. Neptune, and J. C. Bryan. "Determination of Optimum Tropic Storage and Exposure Sites, Report II: Empirical Data," USATTC Report No. 7403001, TECOM Project No. 9-CO-009-000-006, US Army Tropic Test Center, Fort Clayton, Canal Zone, March 1974, AD A005017.

Downs, G. F., R. J. Gorak. "Exposure/Performance Tests of Selected Materiel Items," USATTC Report No. 790102, TECOM Project No. 7-CO-RD5-TT1-016, US Army Tropic Test Center, Fort Clayton, Canal Zone, January 1979.

1.5.4 For the digital electronic system, no deterioration in performance or reliability was noted in any of the test environments. This result is meaningful because it supports the validity of the test design, which requires that materiel items insensitive to degradation in a natural environment should not exhibit degradation patterns in a simulated chamber test.

However, it must be pointed out that the study results are valid for only a 12-month natural exposure period. Materiel items are often required to withstand longer periods in a humid tropic environment. The question then arises--would the performance and reliability of the digital electronic system degrade significantly with additional exposure time? If the answer is yes and if survival of the item is important to the user of the item, then chamber methodologies such as those studied in this investigation may have limited value in predicting long-term humid tropic effects. Long-term (2 to 5 years) exposure studies would be required to investigate this possibility.

1.5.5 For the PHM system, the primary cause of performance deterioration and system failure in the natural environments was corrosion buildup in the hydraulic slave cylinder. The same effect also was observed in the two chamber environments. Statistical analysis of the performance data indicated that there were no statistically significant differences between the severity of performance degradation in the chamber environments and that in the natural environments. The statistical analysis did indicate a moderate delay (estimated to be 45 days) in the onset of performance deterioration of the system at the tropic open exposure site. However, the sparsity of rain at the open exposure site during the first 30 days of the exposure may have contributed to the delay.

In general, performance measurements of the PHM systems in the natural and simulated tropic environments were highly variable. Generally, the means of the performance data decreased with exposure time while the variance of those data increased with exposure time. The pattern reflects the observation that the performance of some systems deteriorated rapidly, while the performance of others showed little or no deterioration with exposure time. High variability of performance data was noted, even for systems exposed in the fungus chamber where temperature and humidity did not differ throughout the test chamber more than 0.6°C (1°F) and 2 percent relative humidity. The causes for the high variability in performance are normally ascribed to the action of microenvironments, to subtle inherent differences among the materiel items or to a combination of both. High item performance variability is a disadvantage to using performance data in the comparison of chamber versus natural environments because large sample sizes may be required to detect, as statistically significant, differences that might be considered to be of practical significance.

1.5.6 Comparisons of the results (tables 1 and 2) obtained in the fungus chamber and greenhouse environments suggest that the greenhouse environment is more representative (with respect to the environmental effects on test item performance and reliability) of the natural environments than is the fungus chamber. Although the statistical confidence of the estimates of the performance parameters presented in tables 1 and 2 is low, because of the high variability of the data and small sample sizes employed by the study, the consistency of agreement between the greenhouse data and the data obtained from the natural environments suggests that the greenhouse methodology is a viable approach for simulation of the natural environment. However, more work on refining the greenhouse methodology is required to determine (1) if the correlations hold when using water representative of natural rainwater for the greenhouse humidity and rain systems, (2) if the correlations hold when using other materiel items and (3) if variations to the greenhouse methodology are required to simulate the various different exposure conditions in the humid tropics.

1.5.7 Statistical analyses of test item performance data and failure data indicate that the onset of performance and reliability degradation in the chamber environments was not significantly different from that in the tropic jungle exposure site. Initial failures in the chamber environments occurred at about 4 months for the optical system and 6 months for the PHM system. This implies that at least a 6- to 12-month exposure period may be required to adequately characterize failures caused by the humid tropic environment.

1.6 CONCLUSIONS

The tropical greenhouse exposure provided a more accurate prediction of tropic performance than did the fungus chamber exposure.

Meaningful acceleration of tropic degradation processes may not be attainable in a tropical greenhouse or in a fungus chamber.

1.7 RECOMMENDATIONS

The tropical greenhouse methodology should not be substituted for field exposure testing until it is further refined and validated.

A cost comparison study should be conducted between chamber testing and field testing in the humid tropics, because system failures and the deterioration of system functions were not accelerated under chamber conditions in this study.

Performance measurements of the PHM systems in the natural and simulated tropic environments were highly variable. High item performance variability is a disadvantage to the use of performance data in the comparison of chamber versus natural environments in that large sample sizes may be required to detect, as statistically significant, differences that might be considered to be of practical significance. Because the variance of item performance responses to environmental factors will be unknown until the items are exposed to a particular environment, it behooves the investigator during the planning stages of the study to judiciously select, with the aid of a statistician, sample sizes which will be sufficient to detect, by means of statistical tests, important differences in the performance of materiel items exposed to chamber and natural environments.

TECOM should fund further studies for refining and validating the tropical greenhouse test methodology to better predict materiel performance in the humid tropics.

SECTION 2. DETAILS OF THE INVESTIGATION

2.1 MATERIALS AND METHODS

2.1.1 Test Environments

Test items were exposed in six environments in this study, three at USATTC and three at ARMTE. An open exposure site (figure 1) and a jungle exposure site (figure 2) on the Pacific side of the Isthmus of Panama in the Canal Zone were used for the USATTC field exposures. These sites were located in the General Purpose Test Area near Chiva-Chiva. The third USATTC exposure, in an air-conditioned laboratory, was used to provide baseline information on test item performance. ARMTE also had an air-conditioned laboratory exposure for a control. In addition, two chamber environments were used. The first test chamber, designated in this report as the fungus chamber, provided controlled temperature and humidity conditions as specified in MIL-STD-810C,[2] Method 508, Fungus. The second test chamber was a tropical greenhouse (figure 3) which was designed to simulate factors found in a natural tropic environment to include: temperature, humidity, rainfall, solar radiation, air movement, salt fall, representative flora and fauna, and soils. Deionized water was used in the fungus chamber to provide for the required humidity values of MIL-STD-810C. Tap water containing high concentration of inorganic salts was used initially in the tropical greenhouse as the source for rain and humidity. During the test, surface accumulation of mineral deposits consisting primarily of sodium and calcium sulfates was noted on the test items and vegetation in the greenhouse (figure 4). As a result, in February 1977, the humidifier in the greenhouse was changed so that deionized water was employed. However, the rain system could not be converted economically; therefore, tap water was retained as the source for rain in the greenhouse.

Figures 5 through 10 illustrate diurnal temperature and relative humidity profiles for the two tropic and the tropical greenhouse exposures. Averaged temperature and relative humidity data collected during the course of the study were used to construct the profiles.

2.1.2 Test Items

The test items consisted of three systems designated as: optical, digital electronic, and PHM. The optical and digital electronic systems were contained within a single metal case (figure 11). The PHM system was a separate unit (figure 12).

The optical/digital electronic systems were placed on exposure in January 1976 by USATTC and in May 1976 by ARMTE. The test items were distributed among the six test environments as follows: 5 to USATTC air-conditioned exposure; 20 to USATTC open exposure; 5 to USATTC jungle exposure; 10 to ARMTE air-conditioned exposure; 15 to ARMTE tropical greenhouse exposure, and 5 to ARMTE fungus chamber exposure. Data collection was terminated after 12 months of exposure. The PHM systems were placed on exposure at the beginning of the rainy season (March 1976) for USATTC and at the beginning

[2] MIL-STD-810C, Environmental Test Methods, 10 March 1975.

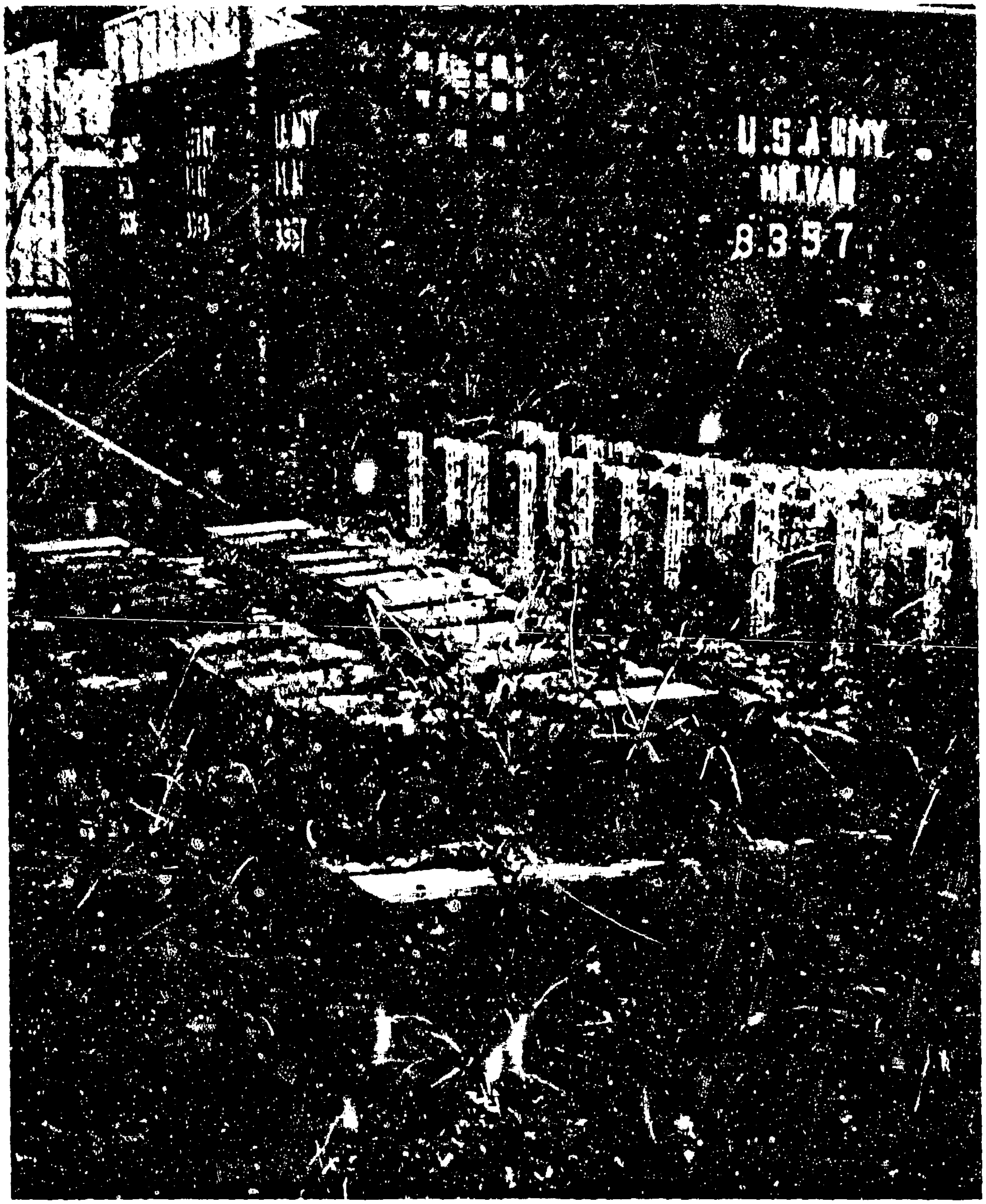


Figure 1. Open Canal Zone Exposure Site.

Figure 2. Jungle Canal Zone Exposure Site.

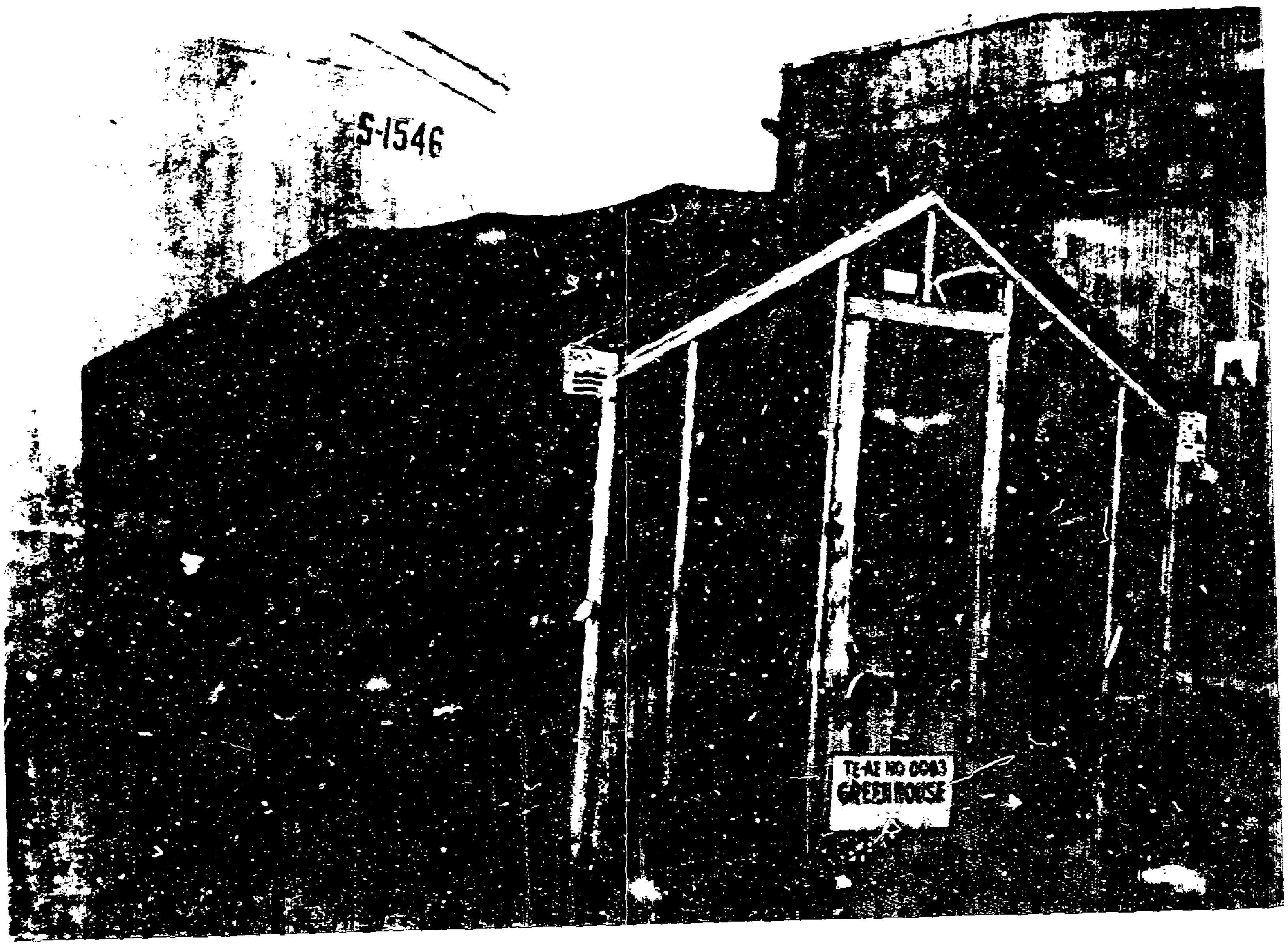


Figure 3. Tropical Greenhouse Exposure—ARMTE.

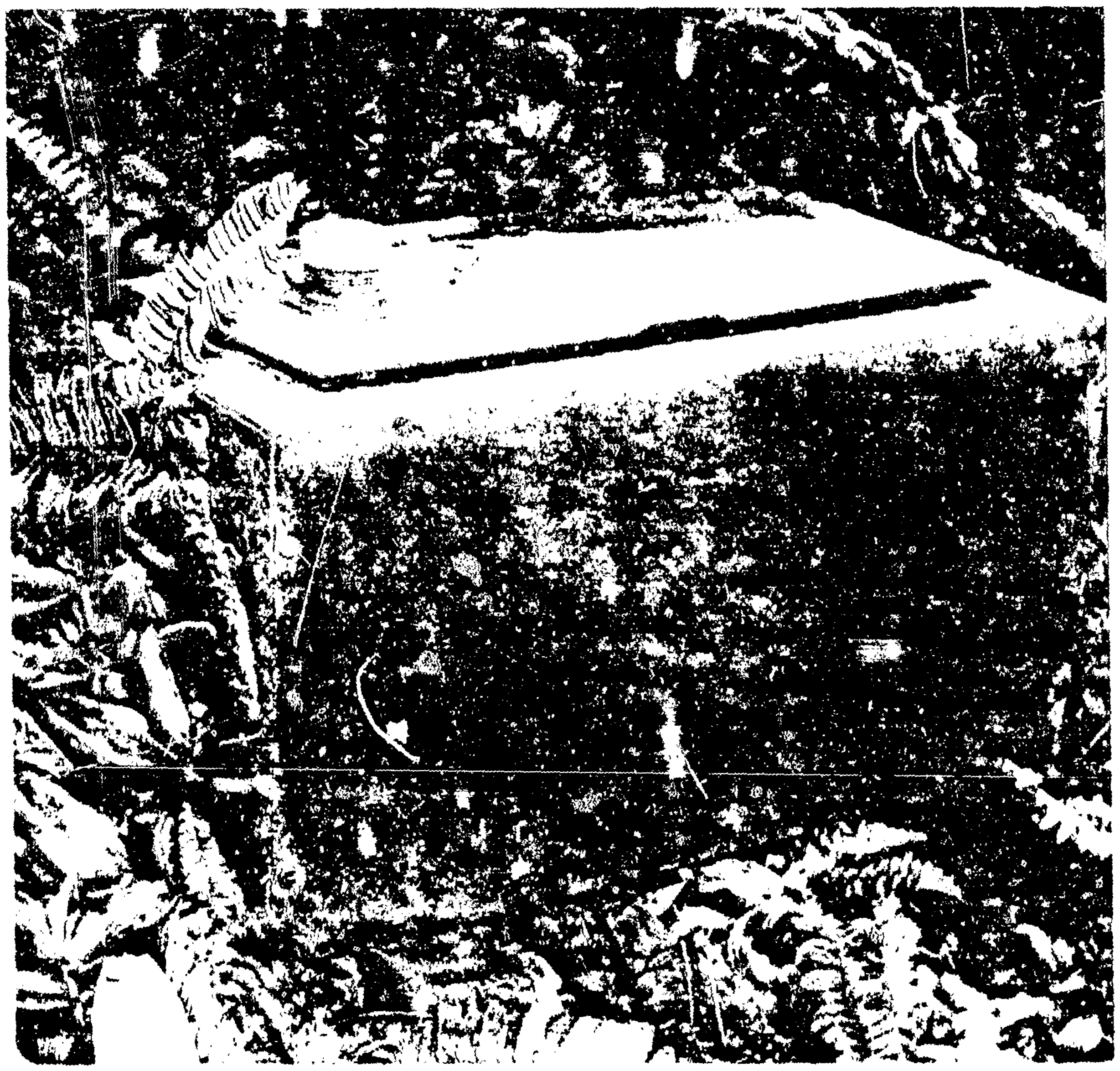


Figure 4. Surface Mineral Deposits on a Tropical Greenhouse Test Item.

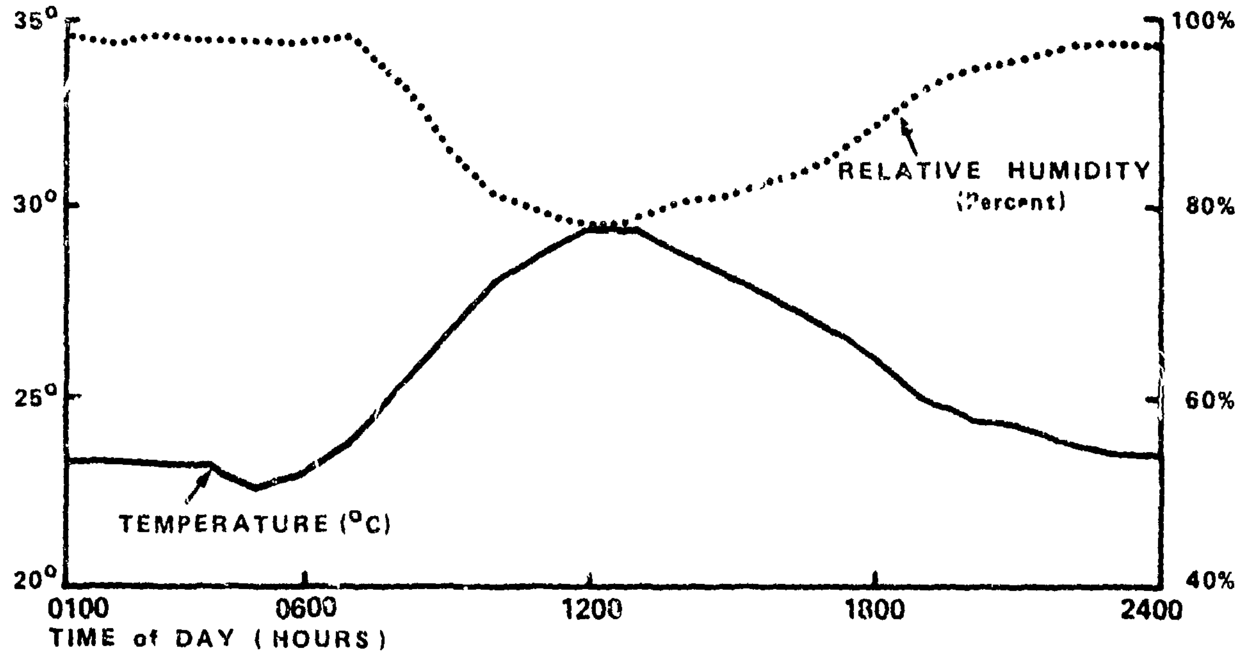


Figure 5. Temperature and Relative Humidity Profile for the Tropic Open Exposure Site, Wet Season.

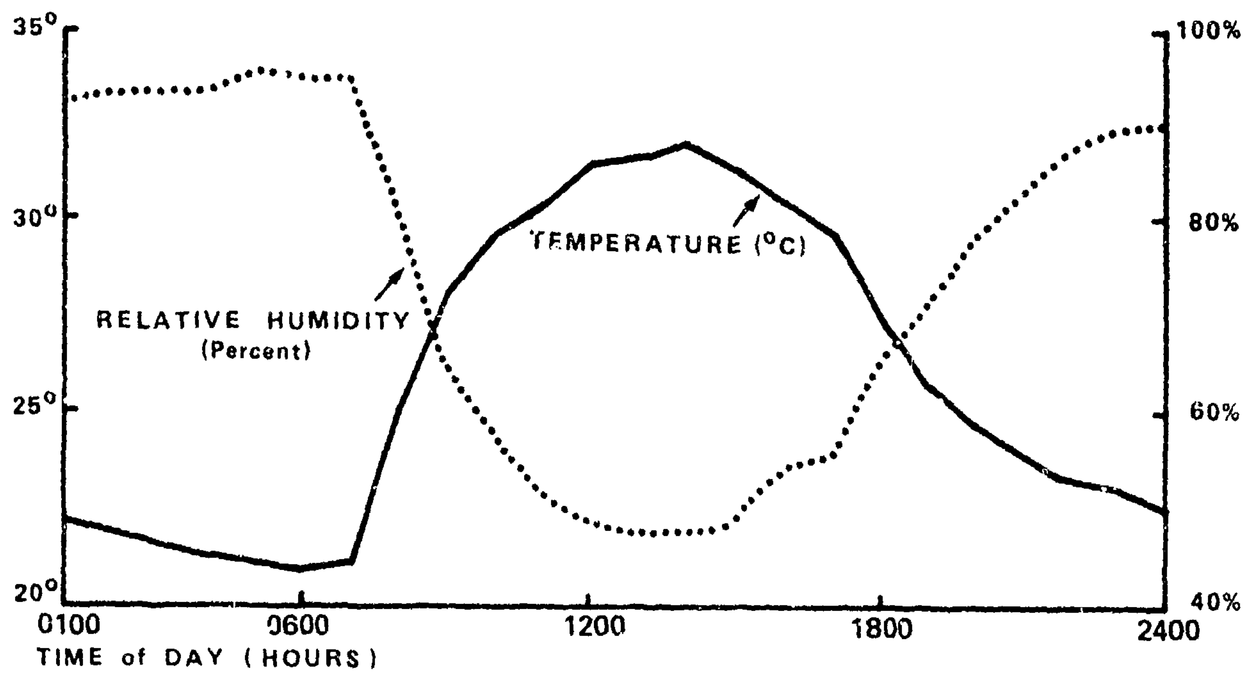


Figure 6. Temperature and Relative Humidity Profile for the Tropic Open Exposure Site, Dry Season.

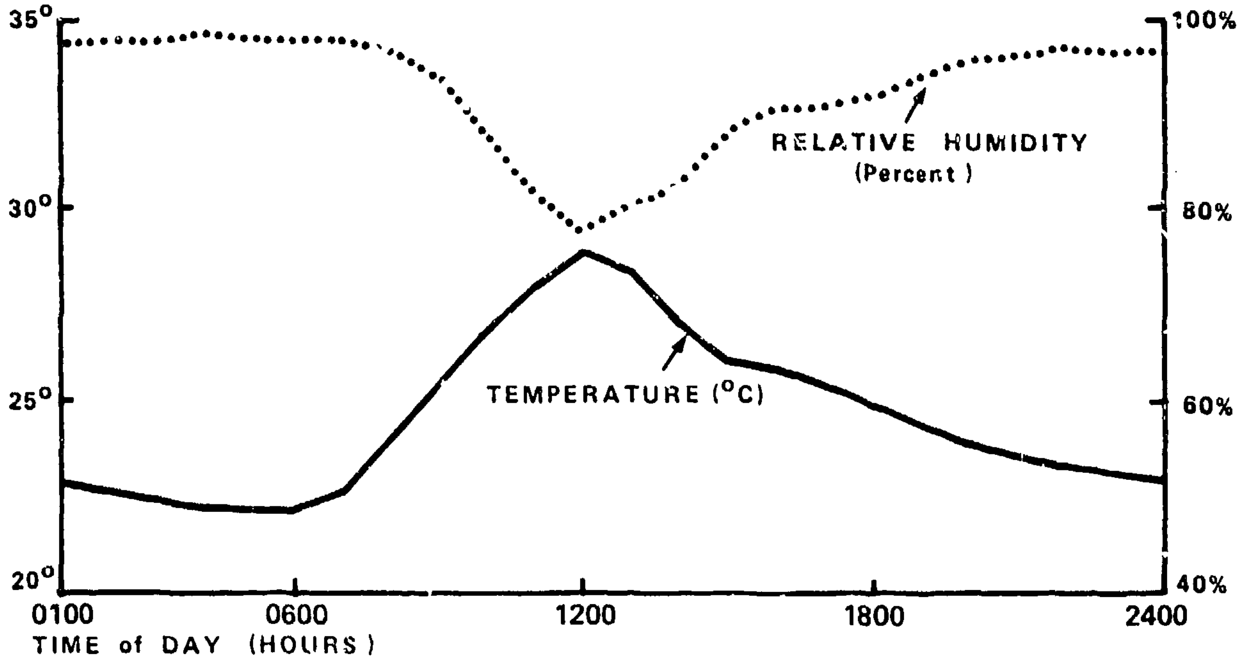


Figure 7. Temperature and Relative Humidity Profile for the Tropic Jungle Exposure Site, Wet Season.

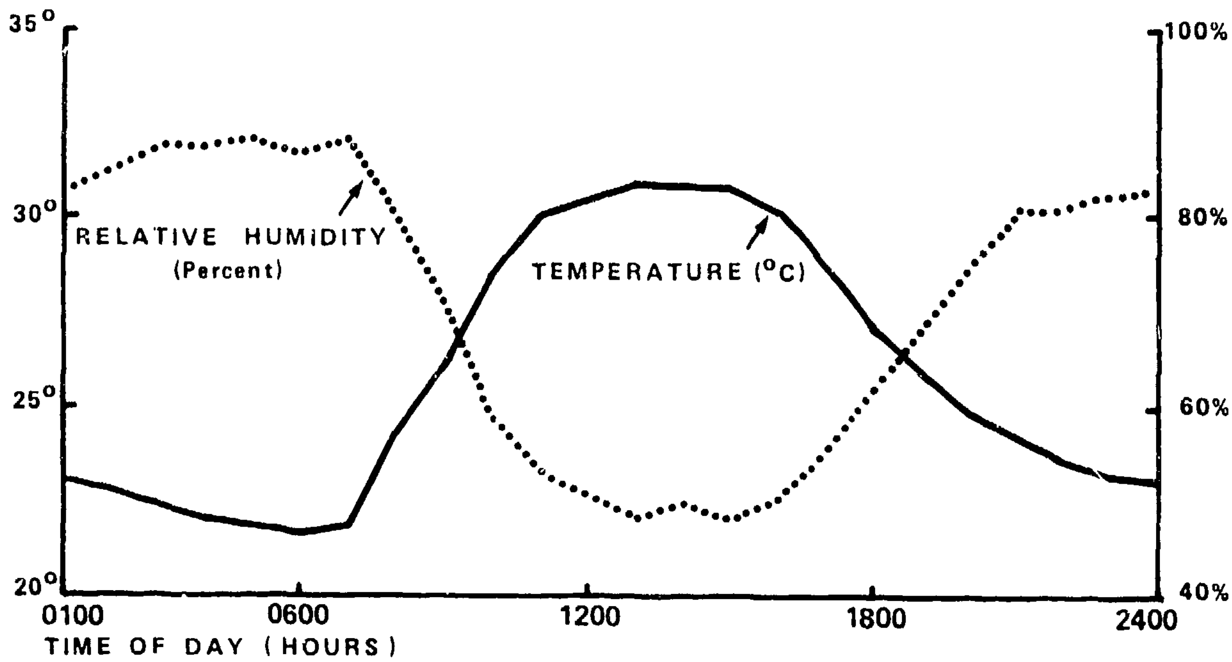


Figure 8. Temperature and Relative Humidity Profile for the Tropic Jungle Exposure Site, Dry Season.

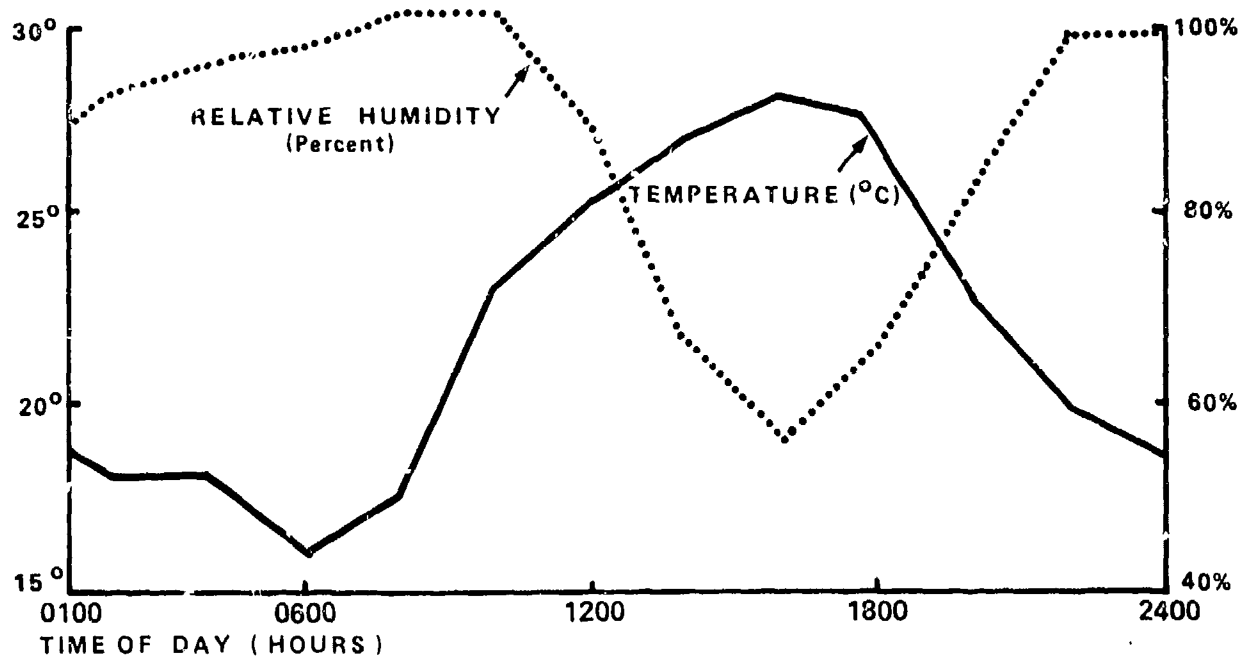


Figure 9. Temperature and Relative Humidity Profile for the Tropical Greenhouse, Summer Months, WSMR.

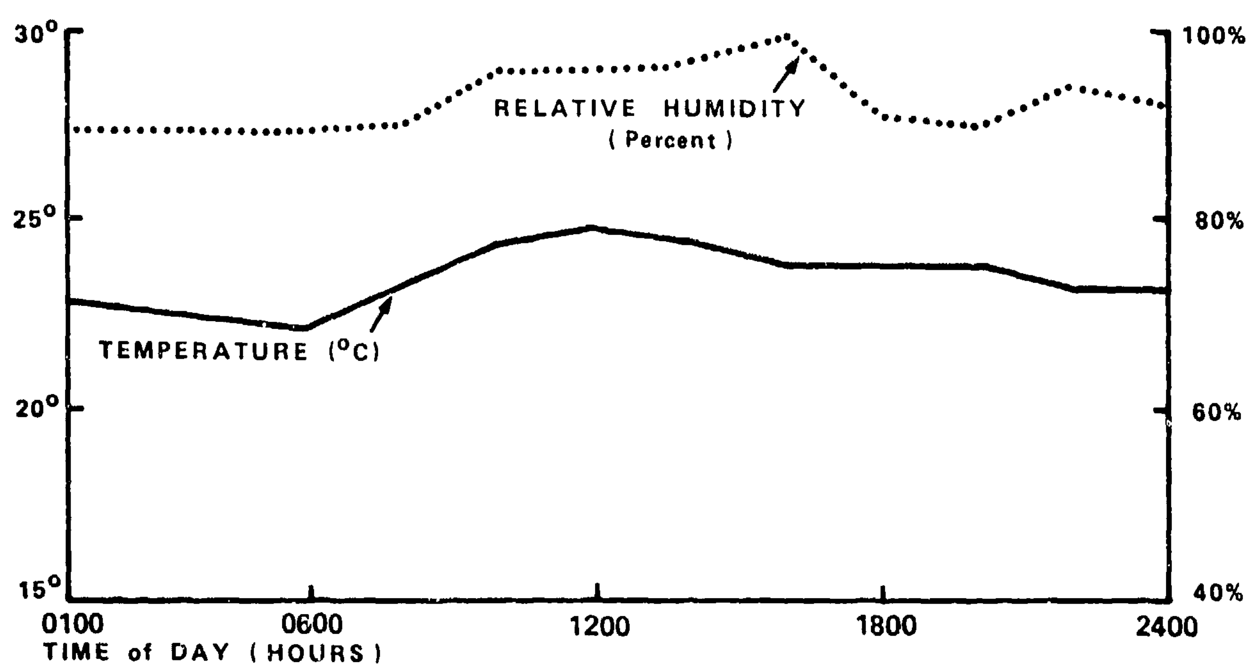


Figure 10. Temperature and Relative Humidity Profile for the Tropical Greenhouse, Winter Months, WSMR.

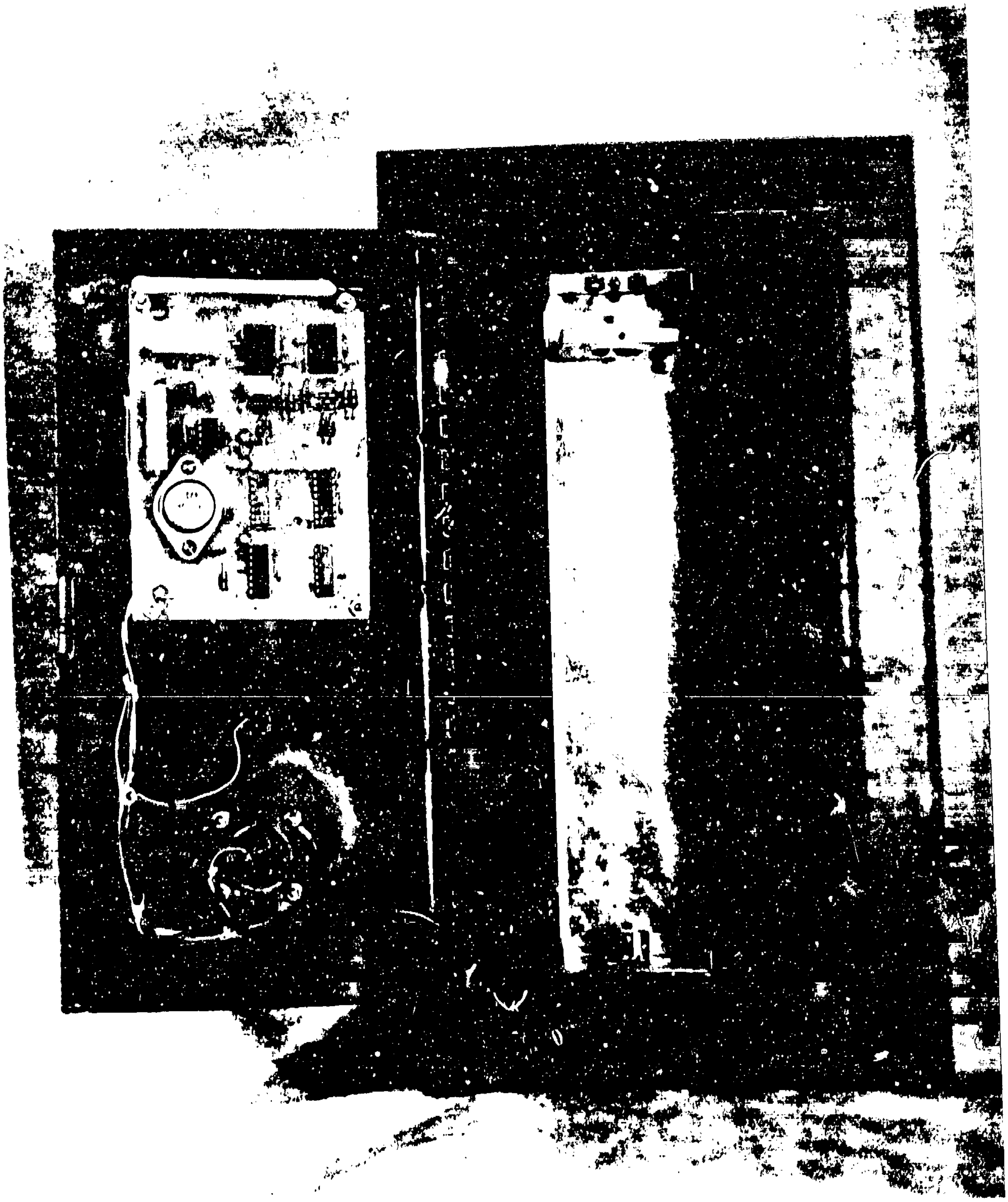


Figure 11. Optical/Digital Electronic Test Item.

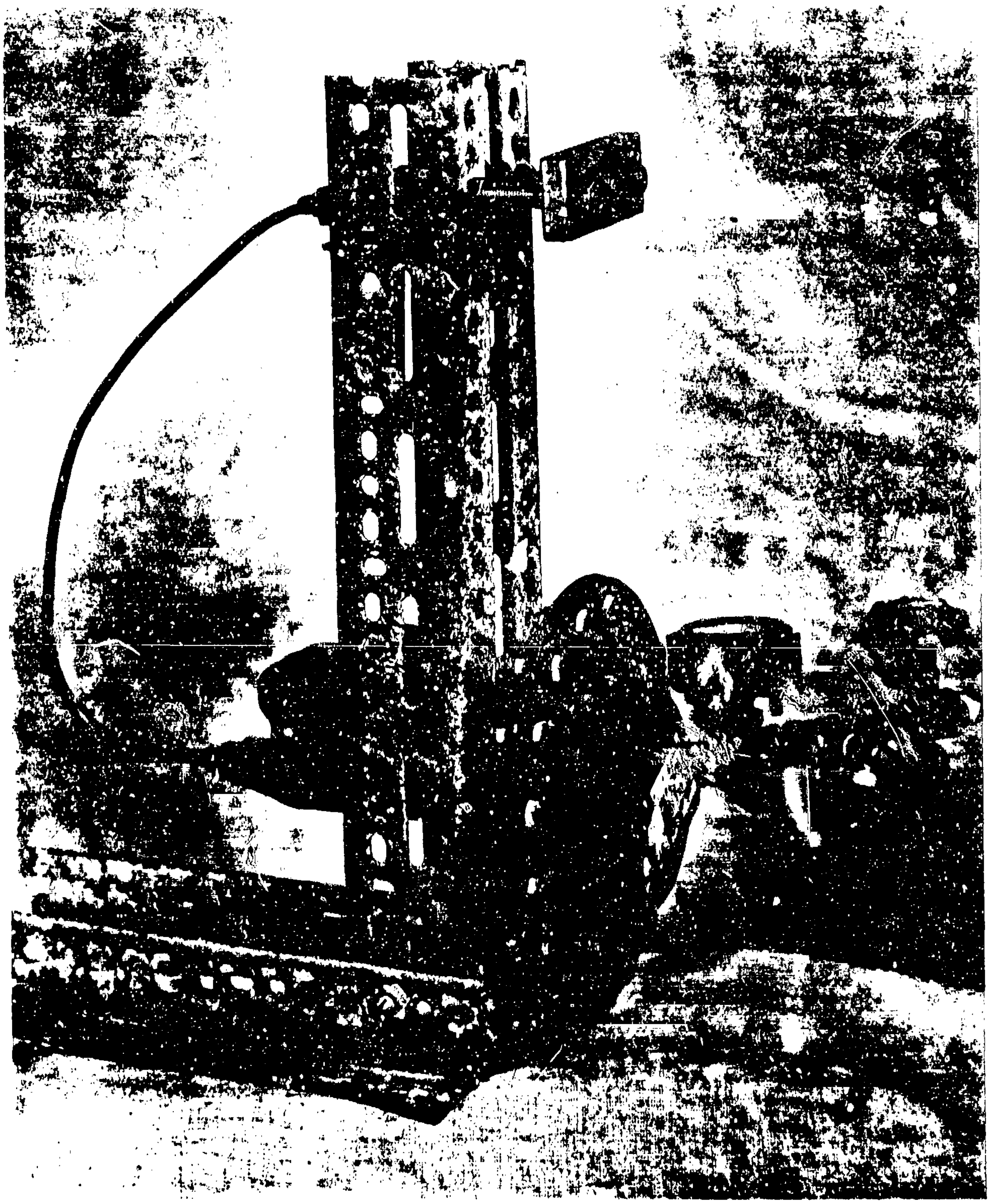


Figure 12. Pneumatic/Hydraulic/Mechanical Test Item.

of the simulated greenhouse rain (September 1976) for ARMTE. Data collection was terminated after 9 months of exposure. The test items were distributed among six test environments as follows: 5 to USATTC air-conditioned exposure, 20 to USATTC open exposure, 5 to USATTC jungle exposure, 5 to ARMTE air-conditioned exposure, 20 to ARMTE tropical greenhouse exposure, and 5 to ARMTE fungus chamber exposure.

2.1.2.1 Optical System

Test Item Description. The optical system was made up of an optical train and the associated analog electronic circuitry required to convert the resistance of a photocell into a voltage reading.

The optics train consisted of a double convex lens which focused light produced by a gallium arsenide phosphide light emitting diode (LED) onto a cadmium sulphide photocell. Power to the LED was supplied from the regulated voltage internal to the electronic circuitry and switched with a section of the digital electronic system.

The analog electronic section consisted of an operational amplifier and associated circuitry required to transform the resistance of the photocell into a corresponding voltage (figure 13). The operational amplifier was configured as a noninverting amplifier. The photocell was located in a resistance ladder comprised of two resisters, R1 and R3, and the photocell. The input signal to the operational amplifier was available at test point TP2. The gain of the amplifier was controlled with potentiometer R2. Prior to exposure, the gain was adjusted to produce a 500 millivolt shift with a 10 percent reduction in the light reaching the photocell. This was accomplished by inserting a calibrated filter in the light path between the lens and the cell, and adjusting R2 to obtain a 500 millivolt shift in the output. The operating point was then adjusted with R1 so that the output without the filter was slightly below the positive rail. This adjustment was necessary because of positive drift in the WSMR units. The reason for the positive drift was not determined. In September 1976, all units were adjusted to an output near "0" volts. Power for the LED was provided from the LM 309 voltage regulator through a section of the reset switch.

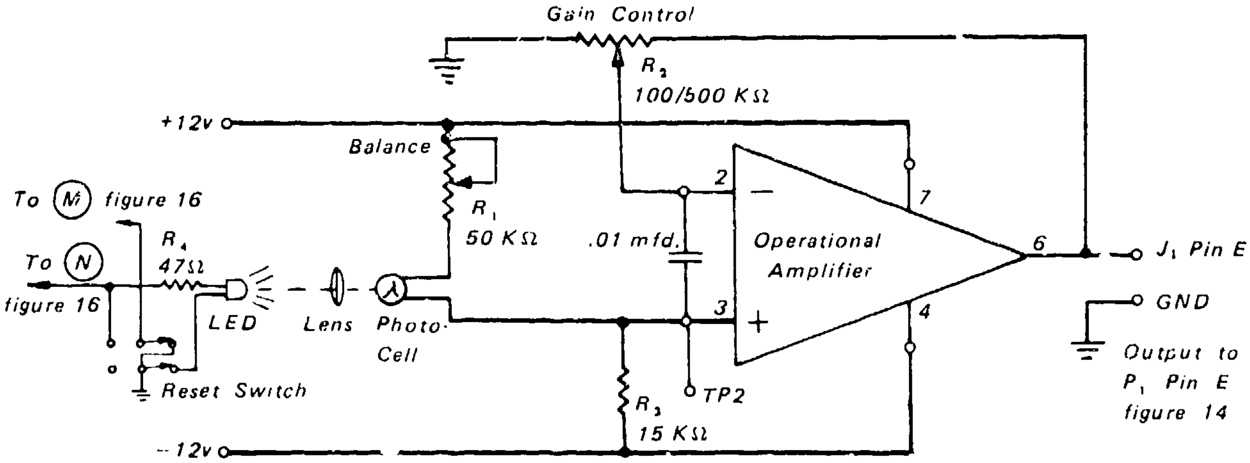


Figure 13. Optical System Schematic.

Tester Description. The optics section of the tester consisted basically of the interconnections and cabling to provide power to and recover signals from the optics section in the test item (figures 14 and 15). A test LED was installed in a test cup. The test LED supplied light directly to the test item photocell, thus bypassing the test item LED and lens system.

Test Procedures. Before performance testing, the test items were examined visually for evidence of deterioration. Step-by-step procedures used in collecting data on the optical and digital electronics systems and the data collection form are included in Appendix B. All measurements were made inside air-conditioned instrumentation vans.

The optical system's performance was determined by monitoring the output voltage from the operational amplifier with the LED on and with a filter inserted in the optical path. A separate LED (from the tester) inserted in the optical path and illuminating the photocell was used to optically bypass the lens and the orginal LED. This tester photocell provided an independent check on the optical analog electronic system.

A system failure was scored when an item failed to operate properly in two sequential inspections. The item was then brought into the lab and the cause of failure identified. If the failure was due to an electronic component, it was scored as an electronics failure and the component was replaced. Malfunctions which disappeared on system drying were not scored as failures.

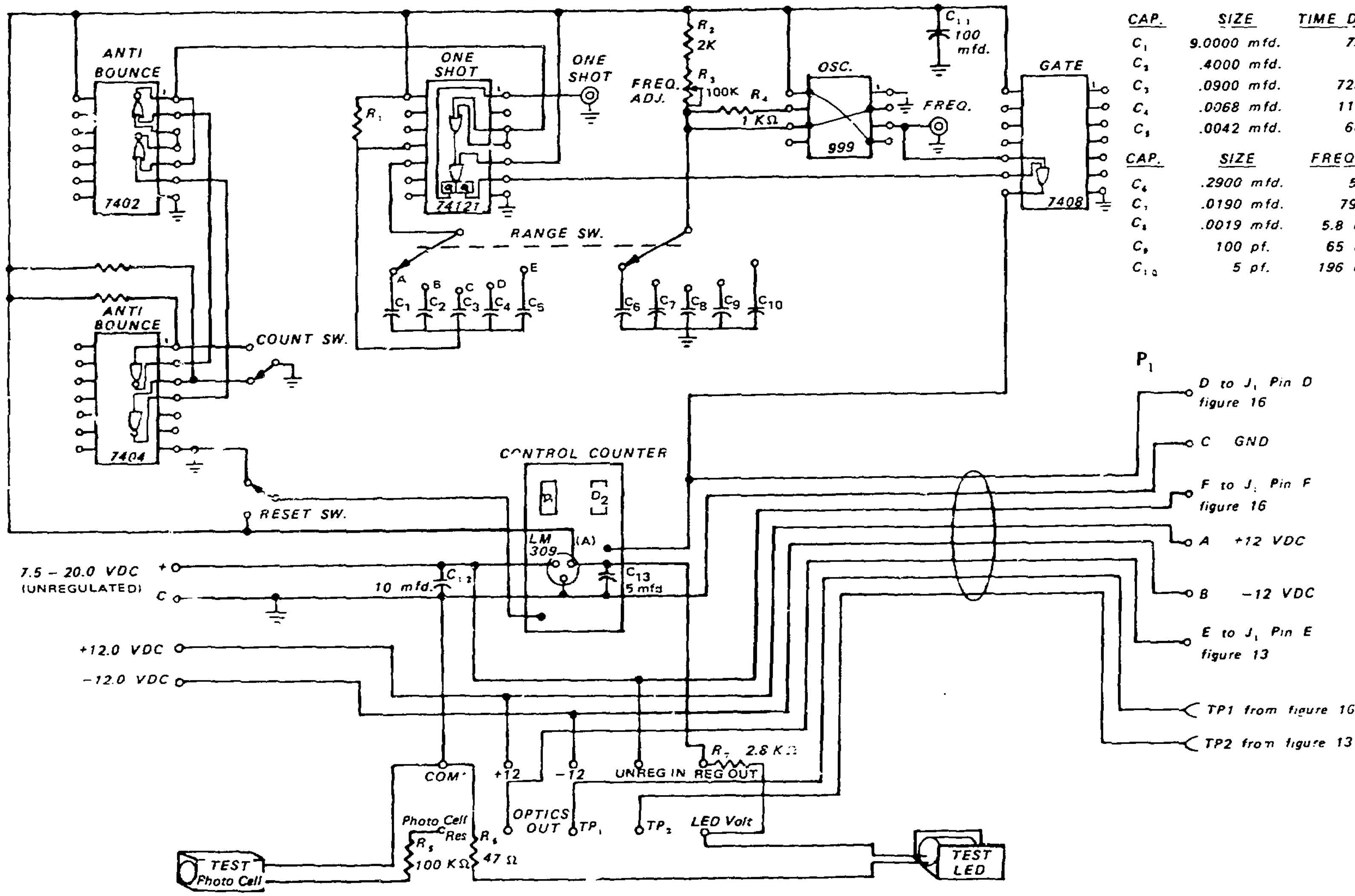
Since valid data could not be obtained if a significant amount of water was present on the circuit board, testing was curtailed during rains. Greenhouse units were isolated from the rain for a period prior to testing. These precautions were instituted after some early data were found to be unuseable because of water on the systems.

Lens transmissivity was measured prior to test initiation and again after test completion. Measurements after exposure termination were made before and after cleaning the lens. The measurements made after cleaning were compared to the original readings to determine if permanent deterioration in the lens had occurred.

Lens transmissivity was measured using an optical bench. An LED and a photocell were mounted on the optical bench 28.5 centimeters apart. The lens was mounted to the system and adjusted to focus light on the photocell and produce a minimum resistance. This resistance was measured using a Fluke 8600A digital multimeter with 5 volts of direct current (DC) powering the LED. All readings were made in a dark room. For a given lens, the lens to photocell distance was kept constant for all readings. The system produced reproducible results since clean lenses, after 1 year of exposure, gave results very close to those obtained for the same lenses when they were new. Transmissivity changes were reported in terms of photocell resistance changes --the greater the resistance change, the greater the fogging of the lens.

2.1.2.2 Digital Electronic System

Test Item Description. The digital electronic system (figure 16) consisted of two integrated circuit TTL decade counters (IC3 and IC4) wired in



CAP.	SIZE	TIME DURATION (sec)
C_1	9.0000 mfd.	79.2 m
C_2	.4000 mfd.	9.0 m
C_3	.0900 mfd.	729.0 μ
C_4	.0068 mfd.	114.0 μ
C_5	.0042 mfd.	68.0 μ

CAP.	SIZE	FREQ. RANGE (hz)
C_6	.2900 mfd.	55 – 1100
C_7	.0190 mfd.	790 – 16.7 K
C_8	.0019 mfd.	5.8 K – 120 K
C_9	100 pf.	65 K – 845 K
C_{10}	5 pf.	196 K – 1.18 M

Figure 14. Optical/Digital Electronic System Tester Schematic.

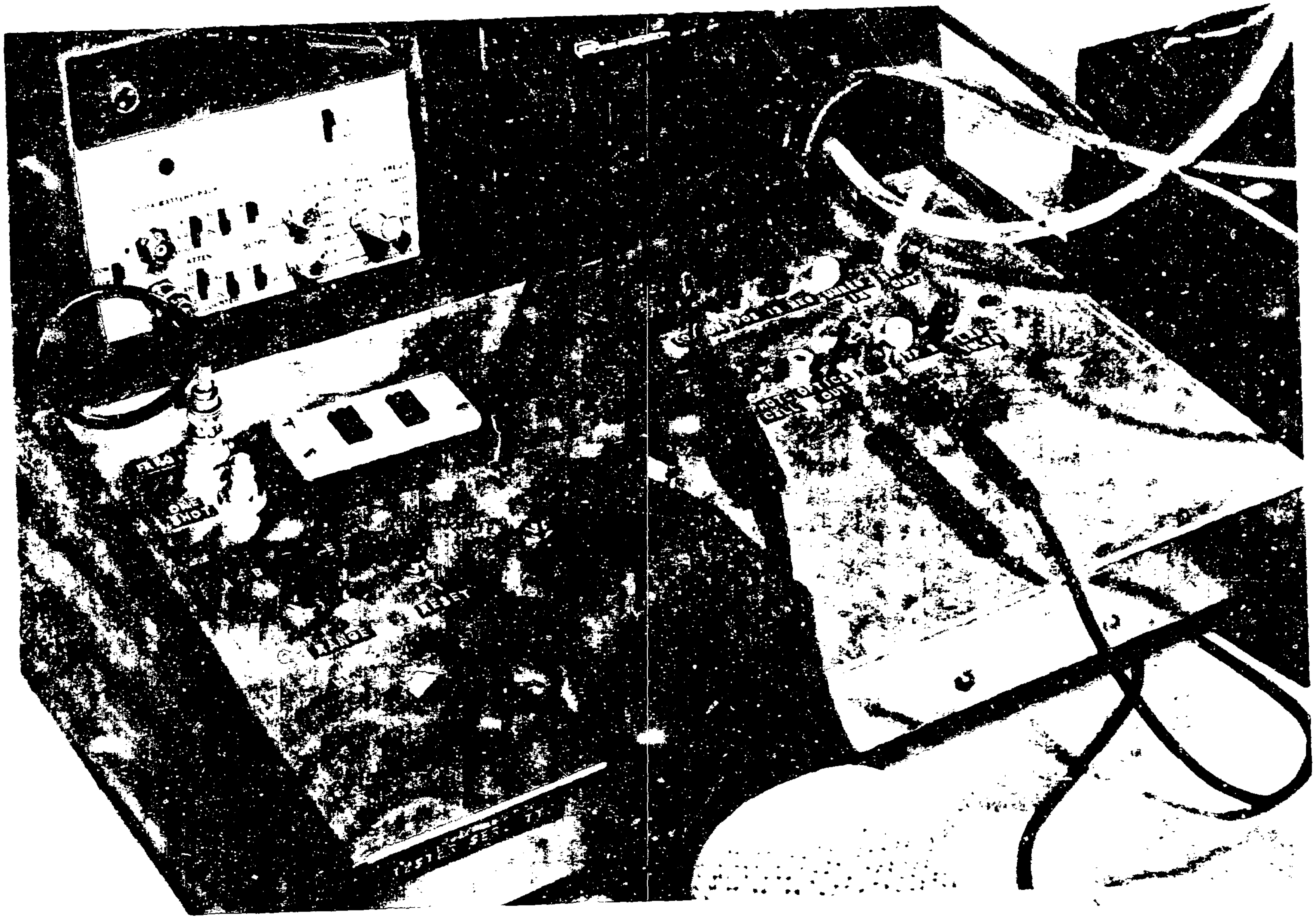


Figure 15. Optical/Digital Electronic System Tester.

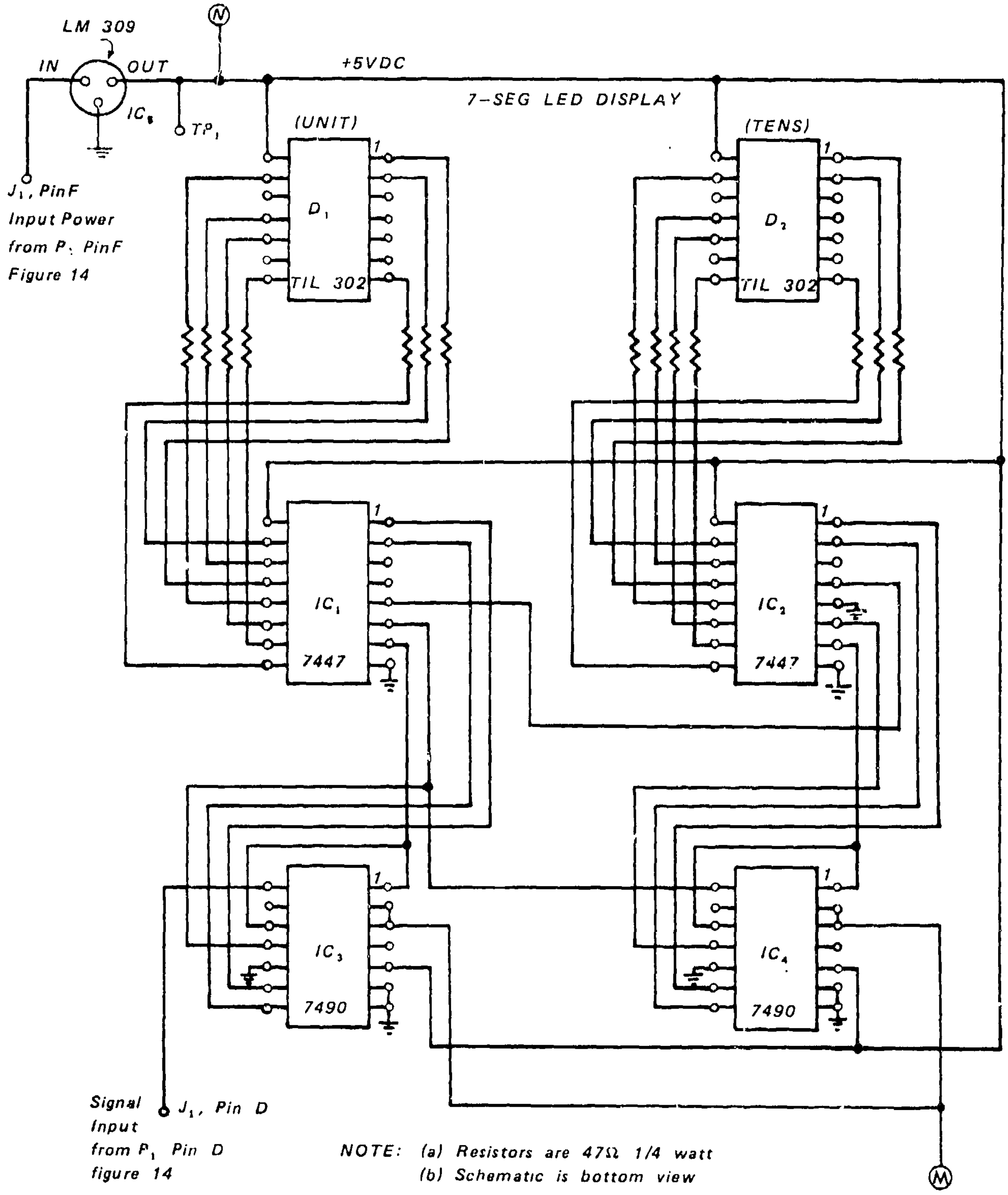


Figure 16. Digital Electronic System Schematic.

tandem. The binary coded decimal output of these counters was decoded by two integrated circuit decoders (IC1 and IC2) to provide the correct code for the seven-segment displays (D1 and D2). The decoders were configured for leading zero suppression. Regulated power was provided for the digital circuit by an integrated circuit switching regulator (IC5). The counter was reset with the momentary pushbutton switch located on the box lid.

Tester Description. The digital test section of the tester (refer back to figure 14) contained a free-running multivibrator, OSC 555. This oscillator ran continuously and was controlled by capacitors C-6 through C-10 and R3. The output of the oscillator provided the basic count frequency for the digital counters in the tester and the test article. This frequency was available on the tester front panel (refer back to figure 15) at the BNC connector labeled "FREQ."

The laboratory frequency counter was connected to this connector. The basic count frequency was applied to one input of an "AND" gate IC 7408. The signal would not pass through the "AND" gate until the gate was armed by the "one shot" IC 74121. The "one shot" was a monostable multivibrator whose "UP" or "HIGH TIME" was controlled by C-1 through C-5. These capacitors, C-1 through C-5, were selected so that the "AND" gate 7408 was not armed long enough for an overflow (greater than 99) to occur in the counter. The "one shot" was toggled with a manual switch on the front panel labeled "COUNT." This switch was debounced with an RS flip-flop formed from IC 7402 and IC 7404. As the count frequency was being increased with C-6 through C-10, the counting window was correspondingly reduced. This was done automatically by ganging the "one shot" and oscillator switches together forming the range switch. The output of the "AND" gate was applied to a two decade counter in the tester (Control Counter) and through Pin D of the output plug to the counter in the test article.

The illuminance of the seven-segment LED display on the test article was measured by placing a cadmium sulphide photocell in a special holder over the display. The resistance of the cell was measured with a digital voltmeter at "PHOTOCELL OUT" on the front panel. A 100-kilohertz resistor, R5, was placed in series with the photocell to reduce the effect of the cell self-heating from the ohmmeter's batteries.

Test Procedures. Step-by-step procedures used in collecting data on the optical and digital electronic systems, and data collection forms, are included in Appendix B. All measurements were made inside an air-conditioned instrumentation van.

Counting accuracies were determined at five basic count frequencies: 1, 10, 100, and 500 kilohertz and 1 megahertz. The numbers displayed on the test item were compared to those on the tester display. Differences greater than one unit were considered malfunctions. Recurring malfunctions were considered failures. Failed items were brought into the lab for troubleshooting. If the failure was due to one of the IC components, the component was replaced.

Illuminance of the LED displays was measured with the numbers "1" and "8" displayed. Measurements were recorded in ohms using the tester photocell. Photocell resistance was inversely proportional to the display light output.

2.1.2.3 Pneumatic/Hydraulic/Mechanical (PHM) System

Test Item Description. The PHM system (refer back to figure 12) consisted of an air-activated hydraulic (pneumatic) master cylinder, connected by a hydraulic line to a small hydraulic slave cylinder. The piston of the slave cylinder exerted its force against a helical coil spring fastened to the mounting frame. A rod passed through the frame and attached to the piston. The system was tested by applying a known air pressure to the master cylinder and measuring the displacement of the slave cylinder piston with a caliper.

Tester Description. The PHM system was tested at two air pressures, 1.8 and 2.8 kilograms per-square-centimeter gauge (25 and 40 pounds per-square-inch gauge). The test apparatus (figure 17) used two pressure regulators to break down the air pressure from a compressed air tank to 25 and 40 pounds per-square-inch gauge (psig). The reduced pressures were applied to the test unit through two control valves. A pressure release valve was used to depressurize the unit.

Test Procedures. The PHM system was tested by pressurizing the unit to 25 psig and measuring piston displacement. The pressure was increased to 40 psig and the displacement again measured. The system was then depressurized to 25 psig and the piston displacement measured a third time. Detailed test procedures are included in Appendix B. All measurements were made inside air-conditioned instrumentation vans.

A PHM system was scored as a failure when no piston displacement was noted at either 25 or 40 psig for two sequential inspections.

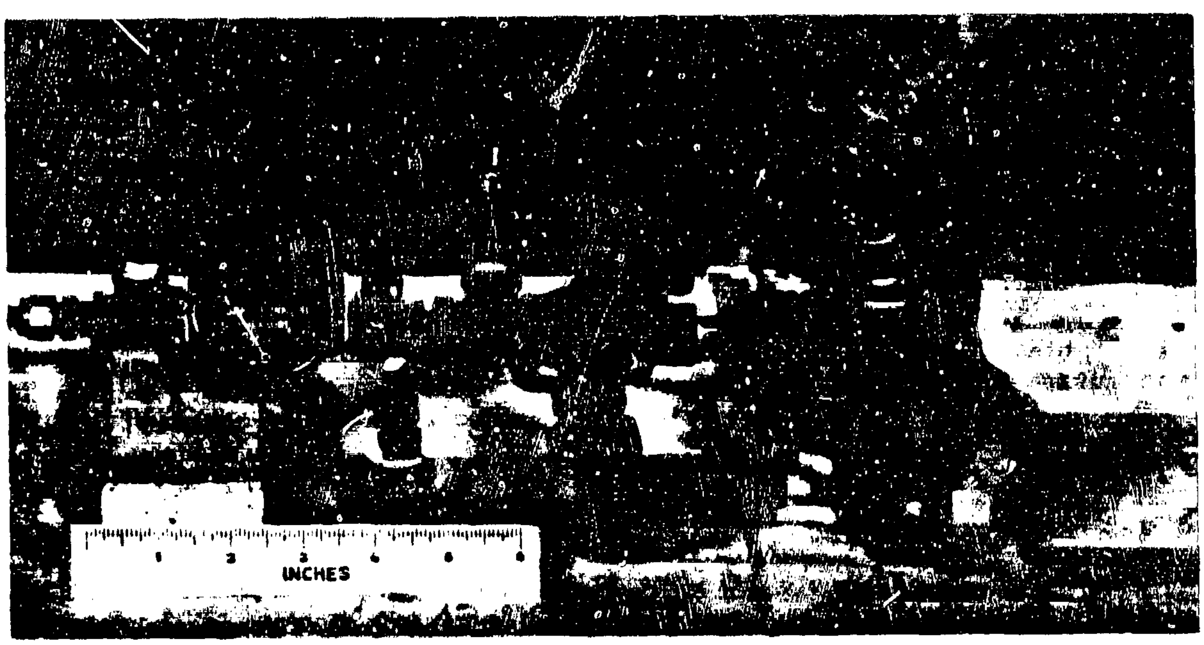


Figure 17. Pneumatic/Hydraulic/Mechanical System Tester.

2.2 RESULTS

This section summarizes the comparison of results obtained from the jungle and open exposure sites with those from the tropical greenhouse and fungus chamber.

2.2.1 Optical System.

System Performance. The optical system consisted of an analog amplifier which was driven by an optical circuit containing an LED feeding through a lens to a photocell which controlled the input to the analog amplifier. The change of lens transmissivity was one measure of system performance used in the study (a reduction in lens transmissivity would reduce the amount of light reaching the photocell, which would, in turn, result in a lower output voltage from the analog amplifier). Lens transmissivity was measured prior to test initiation and again after test completion. Measurements after test completion were made before and after cleaning the lens.

Mean changes in lens transmissivity (measured in terms of photocell resistance changes) for the control optical systems and those exposed in the four test environments are summarized in table 3. Positive changes in resistance (ohms) indicate reduction in lens transmissivity.

Table 3. Lens Transmissivity: Mean Change For Total Test Period (1,000 ohms)

	Uncleaned			Cleaned		
	(Mean)	(SD)	(No.)	(Mean)	(SD)	(No.)
Control	28	25	15	4	9	15
USATTC Jungle	132	73	4	5	10	3b/
USATTC Open	298	142	20	5	13	20
WSMR Greenhouse	975	354	12a/	10	15	12c/
WSMR Fungus Chamber	89	52	5	20	14	5

a/ Does not include three statistical outliers (SNs 4, 9 and 46).
b/ Does not include one statistical outlier (SN 40).
c/ Does not include three statistical outliers (SNs 24, 32 and 41).

Statistical analysis of the transmissivity data of the uncleaned lenses was performed using the test procedure described by Natrella[3] in paragraph 3-3.1.2 of Experimental Statistics. The procedure tests the hypothesis of equality of means between two populations. Tests were performed comparing

[3]Natrella, M. G., Experimental Statistics, National Bureau of Standards Handbook 91, August 1963.

the mean lens transmissivity of each environment with all others. A significance level of 5 percent was chosen for each test. The results of the statistical tests indicated that (1) the mean transmissivities of the lenses from the tropic open exposure and greenhouse environments differed from those of the lenses from the control environment and from the other exposure environments, (2) the mean transmissivity of the lenses from the tropic open exposure environment differed from that of the lenses from the greenhouse environment and (3) there were no significant differences among the mean transmissivities of the lenses from the control, tropic jungle and fungus chamber environments.

Three lenses from the greenhouse environment showed a significantly higher (greater than 3 standard deviations) reduction in transmissivity than that demonstrated by the other lenses from the greenhouse environment. The changes in lens transmissivity for these lenses were 2.5, 4.5 and 5.8 megohms. However, transmissivity for these lenses returned to preexposure values after they were cleaned. In general, reduction in transmissivity for all lenses was due to surface contamination which could easily be removed. Analysis of the samples from the lens surface showed them to be corrosion products from the box containing the electronic and optical systems. No biological activity was observed.

For the cleaned lenses, a one-way analysis of variance (ANOVA) was performed on the transmissivity data to test the hypothesis that the five means of the transmissivity data (control plus four exposure environments) were identical. Table 4 presents the results of the ANOVA.

Table 4. ANOVA to Test the Hypothesis of the Equality of Mean Lens Transmissivity Among the Control and Exposure Environments

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F-Ratio
Among Treatments	4	1,170	292.6	1.86
Within Treatments	50	7,872	157.4	
TOTAL	54	9,042		

Because the observed F-ratio of 1.86 is less than the 95 percent critical F-ratio of 2.54, the hypothesis of identical means was not rejected at the 5-percent significance level.

The above ANOVA did not include transmissivity data of three lenses from the greenhouse environment and one from the tropic jungle environment. These lenses showed a significantly higher (greater than 3 standard deviations) reduction in transmissivity than that demonstrated by the total population of cleaned lenses. The changes in transmissivity for the four lenses were 232, 97 and 89 kilohms for the greenhouse lenses, and 133 kilohms for the jungle lens. These four resistance values represent the following percent changes of the intensity of visible light transmitted through the lenses: 38-, 20-, 19- and 26-percent reduction, respectively.

A second measure of optical system performance was voltage regulator output under several input voltages. All voltage regulator output measurements made during the study were within the required range of 4.5 to 7.0 volts. No meaningful deviations in performance were noted for the voltage regulators exposed at the various test environments. There was only one voltage regulator failure which occurred during the 21st exposure week at the tropic open exposure site. Because the failure was not determined to be a result of an environmental effect, and because the performance of the voltage regulators was satisfactory throughout the study, the failure was considered to be a random failure.

The remaining measures of optical system performance, namely amplifier input and output voltages, were not used to compare test modes. The reason for their not being used was the frequent maintenance performed on the optical systems. The optical system was basically on open-loop system subject to drift and highly sensitive to disturbances. For example, in the presence of water, the system's operational amplifier would frequently be driven to saturation. However, when allowed to dry out, the system normally would recover. Frequent troubleshooting was performed, not only to investigate and correct these system peculiarities, but also to repair system failures. The troubleshooting involved changes to system parameters, such as adjustments of variable resistors and replacement of failed components. These changes to the optical systems destroyed the base for comparison of performance with other units over the 12-month exposure period.

Individual amplifier input and output voltage data did provide essential information for isolating component failures which are discussed below.

Optical System Failures. All optical system failures are tabulated in tables C-1 through C-4 (Appendix C), and data for failure rate calculations are included in table C-6. All failures in the open and jungle exposure sites occurred between 16 and 48 weeks of exposure. The initial failure (that of an operational amplifier) occurred at the open exposure site shortly after the start of the rainy season. The failures in the tropical greenhouse and fungus chamber occurred between 17 and 50 weeks of exposure. Average failure rates for the optical system calculated at the end of the study are presented in table 5

Table 5. Average Failure Rates

Type of Exposure	Failure Rate (failures/1,000 exposure hours)
USATTC Jungle	0.16
USATTC Open	0.03
WSMR Greenhouse	0.12
WSMR Fungus Chamber	0.09

Because the cause of each failure occurrence could not be ascribed directly to evironmental effects, a statistical analysis was performed to determine if the observed failures could be considered as random failures based on the failure data of the devices in the control groups. The statistical test described by Hagan[4] was used to determine if the occurrences of system failure in each exposure mode were significantly greater than those of the control groups. The variable tested was the number of system failures per attempted operations. Table 6 summarizes the data that were tested.

Table 6. Failures Per Attempted Operations

Exposure Period (days)	Jungle	Open	Chamber	Greenhouse	Controls
0-110	0/40	0/160	0/40	0/120	0/120
110-240	5/45	4/180	1/45	6/135	0/135
240-365	2/45	2/180	3/45	10/135	0/135

The analysis indicated that all exposure modes were significantly different from the control mode with respect to the occurrences of system failure. In each case, significant occurrences of system failure were apparent during the last 8 months of exposure. Further analysis,[5] comparing failure data among exposure modes, indicated that the tropic open exposure mode differed from the greenhouse and jungle exposure modes--the greenhouse and jungle exposure modes having a significantly greater number of system failures occurring in the last 8 months of exposure. There were no significant differences in the occurrences of system failures among the remaining environments.

Additional analyses were performed on individual component failures occurring at the various environments to determine if a particular component was significantly inclined to fail in a specific environment. The same procedure used to analyze system failures was employed in the analysis of LED and operational amplifier failures. The analysis was performed on component failure data collected from the 16th exposure week to the end of the study under the assumption that the failure rates of the components were constant over this period. The results of the statistical tests indicated that at a significance level of 0.05, (1) the occurrences of LED failures were not significantly different among the exposure environments and (2) the occurrences of operational amplifier failures at the tropic open exposure site (only one failure occurred) was significantly less than those occurring at the other three exposure environments.

[4]Hagan, John S., "Comparing Binomial Parameters When Sample Sizes are Small," US Army Test and Evaluation Command, Technical Report No. AD-A 1-78, August 1978.

[5]Chi-square tests ($\alpha = 0.05$) were performed on data collected from exposure periods extending over (1) the last 8 exposure months, (2) the last 4 exposure months, and (3) over the middle 4 exposure months. Tests were performed over the latter two exposure periods to consider in the analysis a possible increase in the rate of failure occurrences with exposure time.

2.2.2 Digital Electronic System

System Performance. The counting accuracy of the digital electronic system was a "go/no-go" measure of performance and will be discussed below. The light output of the two seven-segment LED displays was a second measure of performance. Illuminance of the LED displays was measured with the numbers "1" and "8" displayed. Measurements were made using a photocell and were recorded in ohms. For each display, the difference in the measurements between the displayed numbers, "1" and "8", was calculated. These calculated values were then averaged for each inspection and the averages versus exposure time were analyzed using linear regression techniques to determine if significant changes occurred during the exposure period. The procedure of taking differences was used to reduce the systematic errors present in the raw data. The F-statistic was used to test at a significance level of 0.05 for significant trends in the illuminance data. The results of the tests performed for each test environment indicated that there were no significant changes in the illuminances of the LED displays exposed in the various environments during the study.

Digital Electronic System Failures. Of the 60 units exposed for a 1-year period in the various exposure modes, only one system failure was observed. This failure occurred in a unit exposed in the WSMR tropical greenhouse. There was no evidence that this failure was environmentally induced; therefore, the observed failure was considered a random failure. The counting accuracy of all other digital electronic systems remained unchanged over the 1-year exposure period.

2.2.3 PHM System

System Performance. System performance was measured in terms of PHM piston displacement under three input pressure conditions: piston displacement under an input pressure of 25 psig, piston displacement under an input pressure of 40 psig and piston displacement following a return to an input pressure of 25 psig from 40 psig. Percent changes from best estimates of preexposure displacement values were calculated for each measurement of piston displacement which was made during the study. A summary of the performance data for the control and exposure environments is presented in table 7.

The performance data from the control environments were statistically tested to determine if degradation trends were present. A linear model relating performance to exposure time was assumed. Using linear regression techniques, the slope of the regression line was tested to determine if it differed significantly from zero at a significance level of 0.05. The statistical test results indicated that none of the performance parameters of the control test items showed any significant degradation during the time frame of the study.

Figures 18, 19 and 20 present curves of the mean percent changes in the performance parameters versus exposure time for each of the exposure environments. A systematic downward trend in PHM system performance is evident for all four environments. The major changes in system performance for all units were caused by corrosion buildup in the hydraulic slave cylinder.

Table 7. Summary of PHM System Performance Data--Percent Changes of Piston Displacement From Preexposure Values

Exposure Days	JUNGLE SITE 25 psig (Initial) Input Pressure		JUNGLE SITE 40 psig Input Pressure		JUNGLE SITE 25 psig (Return) Input Pressure		OPEN SITE 25 psig (Initial) Input Pressure		OPEN SITE 40 psig Input Pressure		OPEN SITE 25 psig (Return) Input Pressure		USATTC CONTROL 25 psig (Initial) Input Pressure		USATTC CONTROL 40 psig Input Pressure		USATTC CONTROL 25 psig (Return) Input Pressure	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
15	0.8	3.1	1.6	2.9	7.4	9.9	3.6	14.0	0.8	4.3	+ 8.8	12.8	- 2.1	1.8	- 0.7	0.5	13.4	9.2
44	- 9.6	2.9	- 0.7	2.3	1.0	8.6	-13.4	8.8	0.0	2.6	- 0.2	8.9	- 5.3	6.3	- 0.1	1.5	5.1	8.1
58	- 1.3	2.7	1.2	3.4	1.1	8.3	- 5.7	8.8	- 1.5	2.5	- 3.8	9.0	4.5	8.6	0.4	1.8	- 4.7	6.6
78	7.0	1.4	- 2.1	4.0	-11.1	11.6	10.2	9.0	1.2	1.8	- 3.2	7.8	4.4	1.5	2.8	1.8	- 1.6	8.3
92	3.6	4.9	- 4.3	10.0	-10.	29.7	6.5	7.6	- 0.5	3.8	- 1.6	8.0	- 1.4	5.2	- 2.4	2.3	-12.2	11.2
107	- 1.1	16.2	- 6.7	8.5	-26.0	32.5	- 5.1	10.9	- 1.9	3.6	- 8.1	10.0	0.6	10.7	0.2	2.7	0.8	13.2
120	- 5.3	9.0	-11.0	7.4	-36.4	22.9	- 0.5	14.4	- 2.5	5.2	-12.6	15.9	7.1	11.2	- 1.6	1.7	- 6.0	4.8
139	1.1	8.3	- 5.0	7.9	-27.2	32.8	2.1	29.7	2.1	6.5	- 8.1	18.1	10.8	11.4	6.9	4.6	9.7	9.1
156	-30.1	43.4	-12.5	11.7	-52.8	41.6	- 0.1	12.3	- 1.2	7.9	-15.0	20.3	9.8	11.2	2.6	2.3	1.7	6.2
188	-66.5	48.1	-37.3	26.2	-75.3	40.8	-21.5	38.6	-15.3	31.4	-34.7	33.7	0.0	6.0	1.7	1.1	- 0.5	10.5
203	-54.2	42.1	-49.7	30.5	-82.0	35.7	-29.6	37.6	-18.4	33.6	-49.5	35.2	0.8	5.8	1.1	1.5	- 0.6	6.8
231	-81.3	41.8	-68.0	40.5	-85.6	31.5	-62.2	40.1	-39.2	39.2	-69.5	33.7	0.1	3.3	7.7	5.0	14.8	13.6
245	-70.0	45.4	-67.3	42.1	-83.0	36.6	-65.9	37.1	-51.5	38.7	-83.4	26.2	4.2	6.4	2.5	1.0	0.1	7.4
	FUNGUS CHAMBER						GREENHOUSE						WSMR CONTROL					
14	- 4.1	4.0	- 2.1	2.2	-10.4	11.0	3.7	6.0	2.0	2.4	-11.0	11.0	0.3	3.7	- 0.3	1.2	- 4.3	4.1
26	- 5.8	2.4	- 2.9	1.4	- 3.4	8.2	- 1.5	4.2	0.5	3.5	7.2	10.9	- 1.7	2.0	0.6	2.6	8.9	7.6
41	- 3.5	1.6	0.5	0.7	15.7	9.7	- 4.6	4.6	- 1.1	4.0	- 3.1	15.7	- 3.2	7.3	0.0	1.0	12.3	9.6
54	2.3	2.5	2.4	0.8	4.9	8.2	- 4.5	7.8	- 2.5	2.7	- 7.3	13.0	3.0	4.3	- 0.2	0.8	-16.0	2.6
68	11.7	3.8	3.3	1.8	4.1	16.6	6.0	4.6	- 1.3	5.2	4.1	18.7	3.7	1.1	1.0	0.6	- 0.2	9.8
83	0.5	8.0	0.9	2.5	-10.1	10.6	- 2.6	9.0	- 4.2	7.9	-43.8	28.3	2.6	4.0	1.0	0.9	- 6.2	5.5
97	- 2.0	8.0	- 3.5	8.7	3.1	23.1	-10.2	14.9	- 9.8	12.3	-41.0	37.2	2.5	3.9	1.2	1.8	- 8.1	9.0
110	- 3.1	5.9	- 6.2	9.8	-23.6	32.0	-15.5	24.7	-12.8	22.7	-39.1	32.7	0.0	5.3	0.7	1.4	- 2.8	6.2
124	- 7.1	10.5	-10.2	8.0	-35.8	23.1	-18.0	24.3	-13.5	17.9	-44.8	43.4	1.8	4.1	0.4	1.5	-13.6	8.3
138	-17.1	12.9	-18.1	13.5	-72.4	30.7	-22.1	22.5	-18.2	19.7	-66.1	27.2	5.6	4.5	2.9	2.7	- 9.2	17.4
152	-13.9	16.3	-18.6	16.4	-69.0	34.4	-23.8	22.3	-21.0	18.8	-71.8	28.0	8.0	5.2	2.5	3.0	-13.3	5.1
167	0.5	17.9	-17.2	12.4	-72.4	27.6	-28.3	31.3	-22.3	18.2	-68.7	31.5	6.5	4.8	2.7	3.1	-12.6	4.2
181	-14.4	13.5	-18.2	14.6	-62.9	34.5	-24.0	25.5	-22.2	20.2	-71.7	30.7	9.3	17.8	1.5	3.4	5.6	21.4
194	-20.3	14.2	-21.1	14.2	-66.6	30.3	-42.1	31.5	-30.4	24.1	-80.8	23.7	6.9	9.3	3.8	4.7	8.4	5.1
209	-29.3	17.5	-29.2	12.8	-83.2	17.8	-48.6	33.3	-40.6	28.4	-84.5	23.0	7.1	12.1	4.3	5.0	8.3	3.3
223	-20.1	24.4	-28.4	21.4	-89.8	22.0	-59.2	38.9	-51.8	30.1	-94.8	10.9	19.9	13.4	3.6	5.2	- 9.9	4.1
238	-37.3	16.0	-40.3	15.7	-65.6	45.2	-64.3	38.1	-60.4	31.3	-81.2	32.0	18.3	15.1	2.8	5.9	1.4	19.1

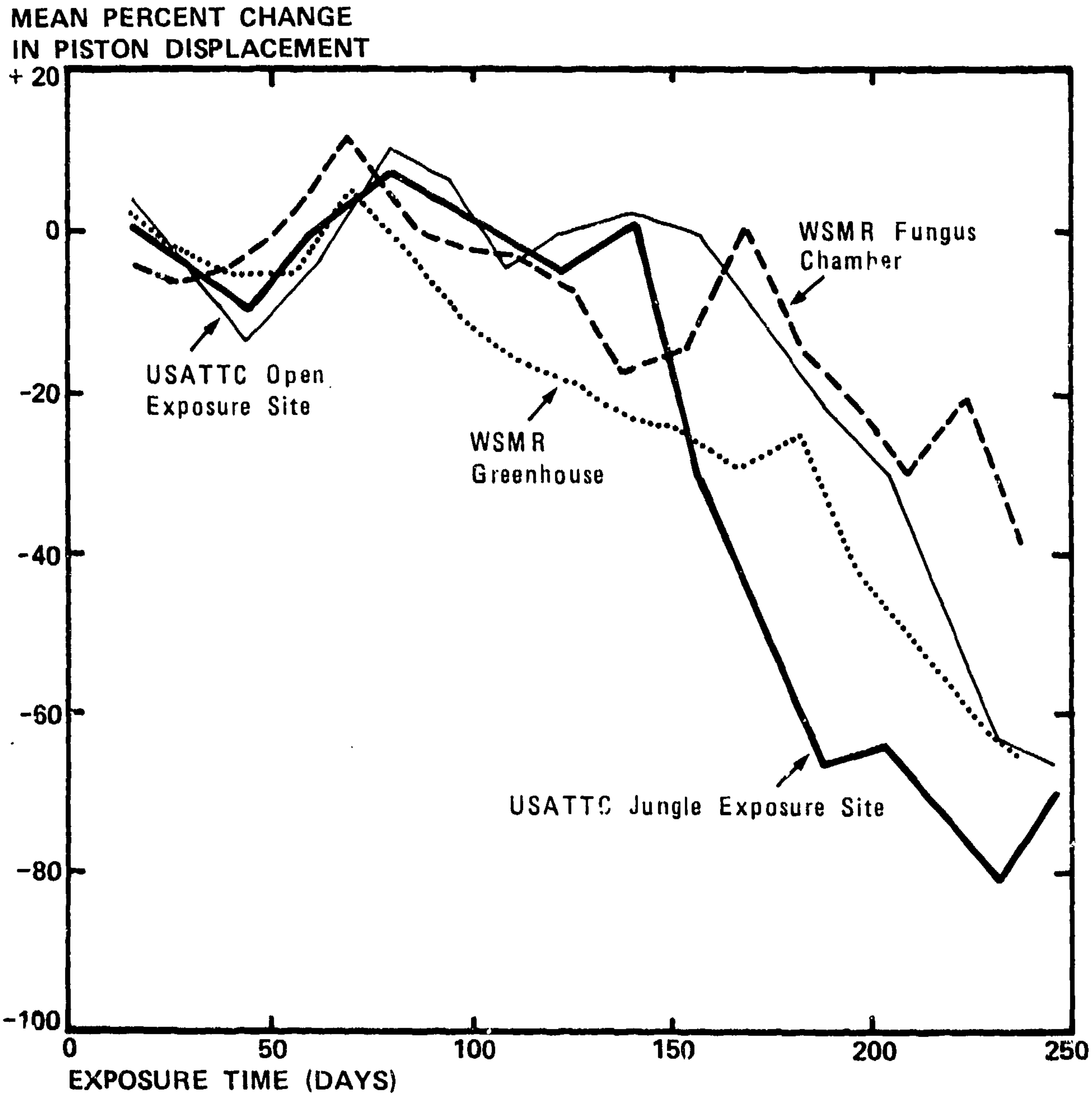


Figure 18. Pneumatic/Hydraulic/Mechanical System Performance Data (25 psig).

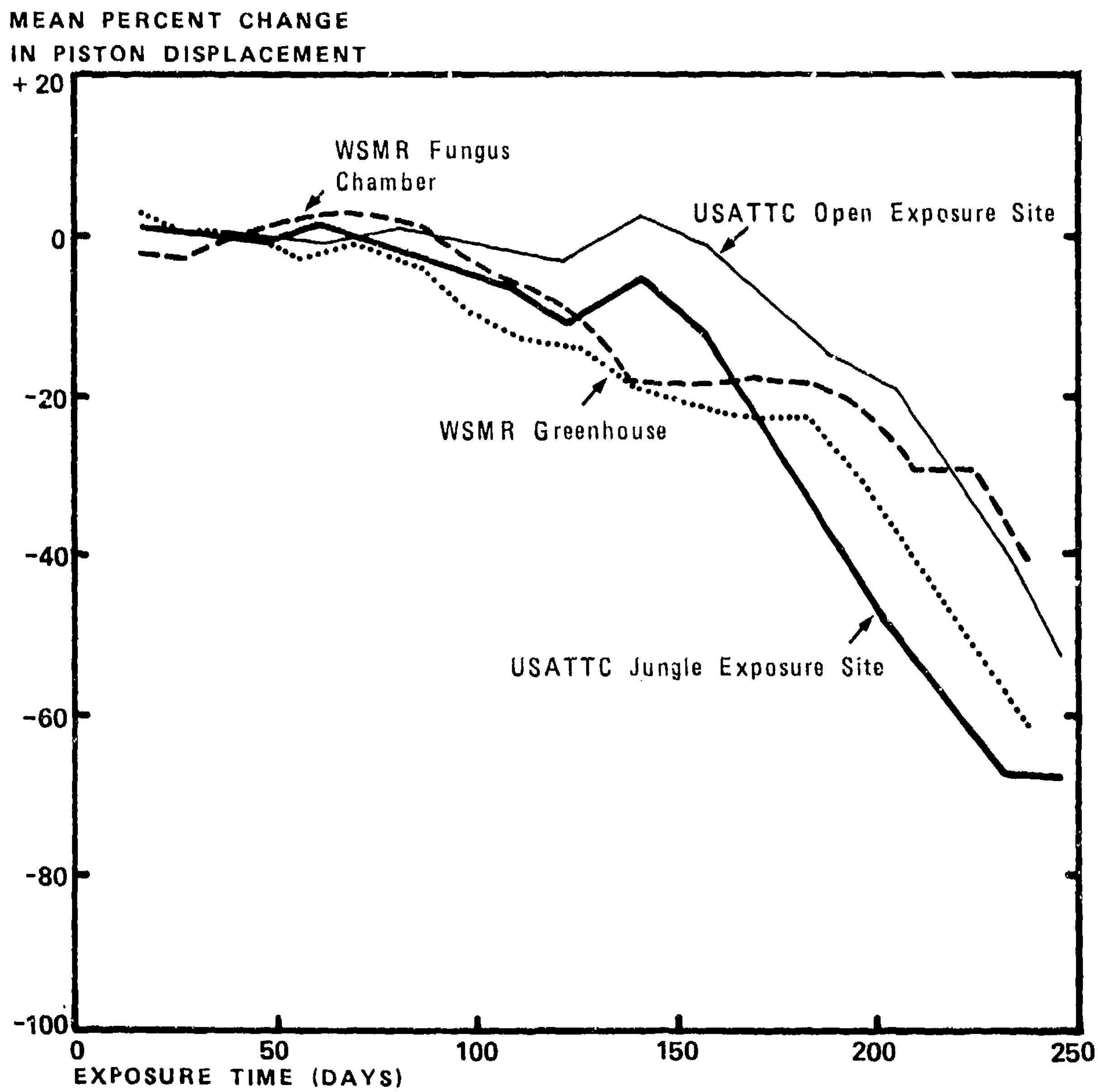


Figure 19. Pneumatic/Hydraulic/Mechanical System Performance Data (40 psig).

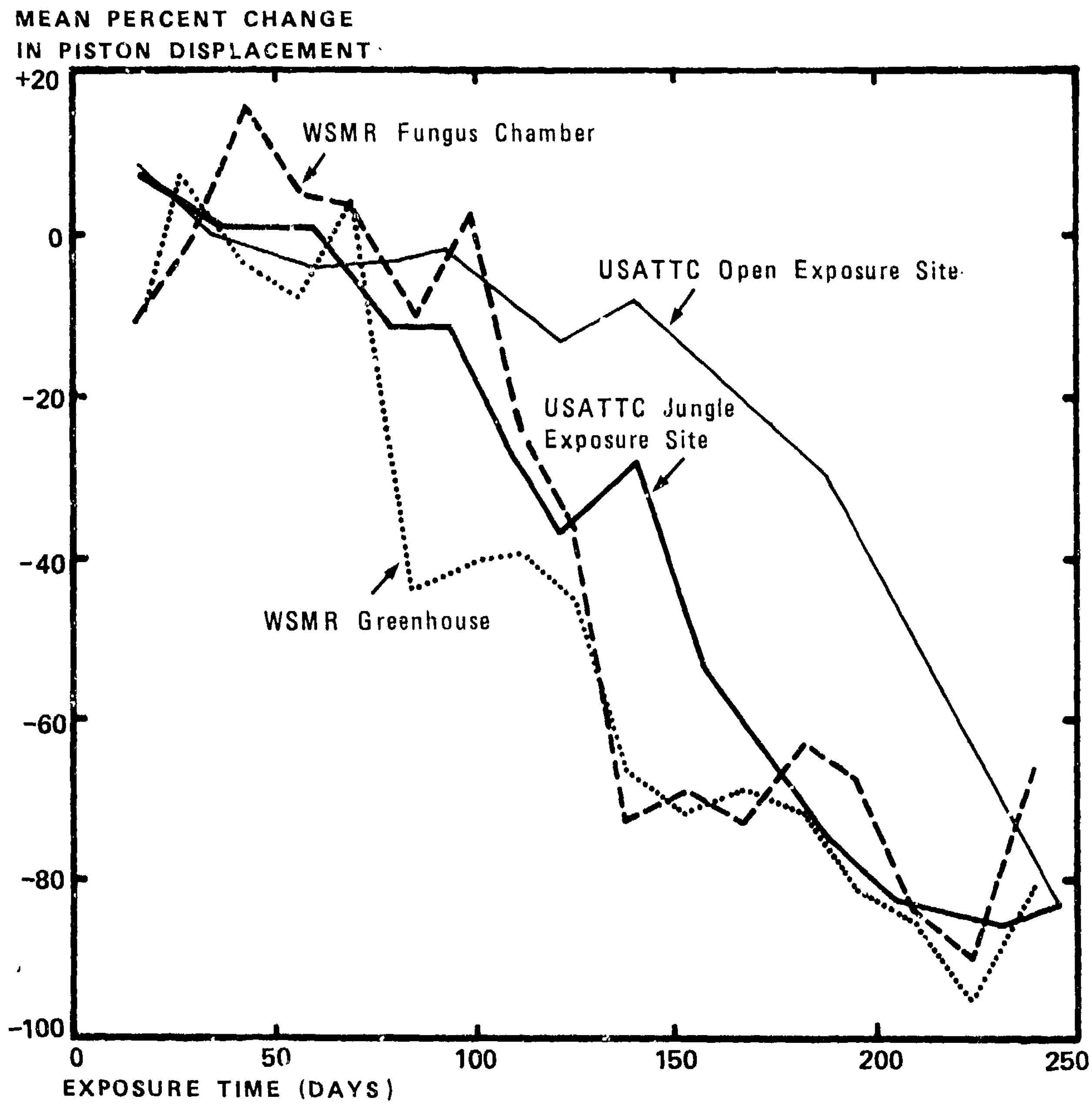


Figure 20. Pneumatic/Hydraulic/Mechanical System Performance Data (Return to 25 psig).

The distributions of performance data at selected points in time are presented in tables 8, 9 and 10 to illustrate the diverse deterioration patterns that are indicated by the standard deviations presented in table 7. The performance of all units within an exposure environment did not deteriorate at the same rate. Some units deteriorated rapidly to failure while others performed well or showed slower rates of deterioration. For example, USATTC Jungle Unit number 10 showed significant (greater than 3 standard deviations) performance deterioration after 92 exposure days, while USATTC Jungle Unit number 6 showed no significant ($\alpha = 0.05$) performance deterioration after 245 exposure days.

To determine if the performance data from the different exposure environments were statistically equivalent, two-sided ($\alpha = 0.05$) Kolmogorov Smirnov distribution-free tests[6] were performed. The performance parameters that were analyzed were the percent changes of PHM piston displacement under the various input pressures. The statistical tests were performed on the distributions of the performance parameters at discrete exposure times approximately 1 month apart. The results of the tests are presented in table 11. No significant differences between the performance distributions of the jungle exposure site and fungus chamber PHM systems, or between those of the jungle exposure site and greenhouse systems were indicated by the test; therefore, these results were not included in the table.

The test results indicated that there were significant differences between the distribution of the performance data of the tropic open environment and the other environments over a portion of the exposure period. A closer examination of figures 18, 19 and 20 indicated that the differences may have resulted from the fact that the onset of performance deterioration in the systems at the open exposure site was lagging behind that of the other environments. An estimate for this lag is 45 days. (The estimate was obtained simply by shifting the performance data curves for the open exposure site to the left on figures 18, 19 and 20.) A partial explanation for the lag might be the lack of rain occurring during the first 30 days of exposure at the open exposure site. A total of 0.4 centimeters (0.16 in) of rain was recorded during this time period at the open exposure site.

Significant differences in system performance for one of the input pressures (25 psig return) were also detected between the systems of the greenhouse and fungus chamber environments at 97 exposure days. This difference was a result of the rapid deterioration in performance of 8 of the 20 PHM systems in the greenhouse environment.

To quantitatively present the degree of association among the test environments with respect to the performance curves in figures 18 through 20, correlation coefficients were calculated. The average percent change in piston displacement for each WSMR inspection was used as the basis for comparing USATTC results. The USATTC data were interpolated to conform to WSMR lengths of exposure. The paired data for each WSMR inspection day were used to calculate correlation coefficients for all pairs of USATTC and WSMR data. Tables 12, 13 and 14 present the correlation coefficients for each of the performance parameters.

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[6]Hollander, Myles and Douglas A. Wolfe, Nonparametric Statistical Methods, pp. 219-221, John Wiley and Sons, New York, 1973.

Table 8. Distributions of Percent Changes in Piston Displacement for PHM Systems at 25 psig Input Pressure

	USATTC Jungle Exposure Site				USATTC Open Exposure Site			
	Exposure Time				Exposure Time			
	2 mo.	4 mo.	6 mo.	8 mo.	2 mo.	4 mo.	6 mo.	8 mo.
100-80%	5	5	1	1	19	19	15	4
80-60%	-	-	1	-	1	1	1	1
60-40%	-	-	-	1	-	-	-	5
40-20%	-	-	-	-	-	-	1	-
20- 0%	-	-	3	3	-	-	3	10

	WSMR Fungus Chamber				WSMR Greenhouse			
	Exposure Time				Exposure Time			
	2 mo.	4 mo.	6 mo.	8 mo.	2 mo.	4 mo.	6 mo.	8 mo.
100-80%	5	4	4	-	20	13	12	4
80-60%	-	1	1	3	-	4	4	4
60-40%	-	-	-	2	-	2	2	2
40-20%	-	-	-	-	-	-	1	-
20- 0%	-	-	-	-	-	1	1	10

Table 9. Distributions of Percent Changes in Piston Displacement for PHM Systems at 40 psig Input Pressure

	USATTC Jungle Exposure Site				USATTC Open Exposure Site			
	Exposure Time				Exposure Time			
	2 mo.	4 mo.	6 mo.	8 mo.	2 mo.	4 mo.	6 mo.	8 mo.
100-80%	5	4	1	1	20	20	17	5
80-60%	-	1	2	-	-	-	-	6
60-40%	-	-	1	1	-	-	1	1
40-20%	-	-	1	-	-	-	-	1
20- 0%	-	-	-	3	-	-	2	7

	WSMR Fungus Chamber				WSMR Greenhouse			
	Exposure Time				Exposure Time			
	2 mo.	4 mo.	6 mo.	8 mo.	2 mo.	4 mo.	6 mo.	8 mo.
100-80%	5	5	3	-	20	14	11	2
80-60%	-	-	2	2	-	4	5	6
60-40%	-	-	-	3	-	1	3	2
40-20%	-	-	-	-	-	1	1	4
20- 0%	-	-	-	-	-	-	-	6

Table 10. Distributions of Percent Changes in Piston Displacement for PHM Systems at 25 psig Return Input Pressure

	USATTC Jungle Exposure Site				USATTC Open Exposure Site			
	Exposure Time				Exposure Time			
	2 mo.	4 mo.	6 mo.	8 mo.	2 mo.	4 mo.	6 mo.	8 mo.
100-80%	5	2	1	1	19	14	6	-
80-60%	-	1	-	-	1	5	8	2
60-40%	-	1	-	-	-	1	2	3
40-20%	-	1	1	-	-	-	1	1
20- 0%	-	-	3	4	-	-	3	14

	WSMR Fungus Chamber				WSMR Greenhouse			
	Exposure Time				Exposure Time			
	2 mo.	4 mo.	6 mo.	8 mo.	2 mo.	4 mo.	6 mo.	8 mo.
100-80%	5	2	-	2	16	6	1	2
80-60%	-	-	1	-	4	5	3	2
60-40%	-	2	2	-	-	2	3	1
40-20%	-	1	-	-	-	1	3	-
20- 0%	-	-	2	3	-	6	10	15

Table 11. Results of Statistical Comparisons of Performance Distributions at Discrete Times Among Study Environments

Jungle Versus Open

	Exposure Days						
Input Pressure	92	120	156	188	203	231	245
25 psig (initial)	-	-	-	-	-	-	-
40 psig	-	a/	a/	a/	-	-	-
25 psig (return)	-	a/	-	a/	a/	-	-

Chamber Versus Greenhouse

	Exposure Days					
Input Pressure	97	124	152	181	209	238
25 psig (initial)	-	-	-	-	-	-
40 psig	-	-	-	-	-	-
25 psig (return)	a/	-	-	-	-	-

a/ Distributions of performance data are significantly different at the 0.05 level

Table 11 (cont)

Open Versus Chamber

Input Pressure	Exposure Days (USATTC-WSMR) 92-97	120-124	156-152	188-181	203-209	231-238	245-238
25 psig (initial)	-	-	a/	-	-	-	-
40 psig	-	-	a/	-	a/	-	-
25 psig (return)	-	-	a/	-	a/	-	-

Open Versus Greenhouse

Input Pressure	Exposure Days (USATTC-WSMR) 92-97	120-124	156-152	188-181	203-209	231-238	245-238
25 psig (initial)	a/	-	a/	-	a/	-	-
40 psig	a/	-	a/	a/	a/	a/	-
25 psig (return)	a/	a/	a/	a/	a/	-	-

a/ Distributions of performance data are significantly different at the 0.05 level

Table 12. Correlation Coefficients for PHM System Performance Data at 25 psig Input Pressure

	WSMR Fungus Chamber	USATTC Jungle Exposure Site	USATTC Open Exposure Site
WSMR Greenhouse	0.87	0.91	0.89
USATTC Open	0.79	0.88	-
USATTC Jungle	0.78	-	-

Table 13. Correlation Coefficients for PHM System Performance Data at 40 psig Input Pressure

	WSMR Fungus Chamber	USATTC Jungle Exposure Site	USATTC Open Exposure Site
WSMR Greenhouse	0.96	0.96	0.93
USATTC Open	0.85	0.95	-
USATTC Jungle	0.91	-	-

Table 14. Correlation Coefficients for PHM System Performance Data at 25 psig Return Input Pressure

	WSMR Fungus Chamber	USATTC Jungle Exposure Site	USATTC Open Exposure Site
WSMR Greenhouse	0.92	0.93	0.80
USATTC Open	0.76	0.90	-
USATTC Jungle	0.90	-	-

PHM System Failures. All PHM system failures are tabulated in table C-5 (Appendix C) and data for failure rate calculations are included in table C-7. Average failure rates were 0.068, 0.060 and 0.053 failures per 1,000 exposure hours for the jungle and open exposure sites and the tropical greenhouse, respectively. The fungus chamber had no system failures. Initial failures occurred at 27, 28 and 33 exposure weeks in the open exposure site, tropical greenhouse and jungle exposure site, respectively.

The PHM system failure data were statistically tested assuming that the number of failures occurring after 34 weeks of exposure is distributed binomially, with parameter "p" being equal to one minus the probability of survival. Table 15 presents the data that were analyzed using the Chi-square statistic to test equality of the probability of survival after 34 exposure weeks in the various environments.

Table 15. PHM System Failure Data after 34 Weeks of Environmental Exposure

Exposure Site	Number of Failures	Number of Systems Exposed
USATTC Jungle	2	5
USATTC Open	5, 6 or 7a/	20
WSMR Greenhouse	6	20
WSMR Fungus Chamber	0	5

a/ Because failure data were collected by USATTC at 33 and 35 exposure weeks, three statistical tests were performed to consider all possible numbers of failures that may have occurred at the open exposure site after 34 weeks of exposure.

The test results indicate that there were no significant differences in the numbers of failures occurring at the various exposure sites after 34 exposure weeks.

2.3 ANALYSIS AND DISCUSSION

2.3.1 Chamber and Natural Environment Correlations

For chamber results to be useful in predicting test item performance in the field, the following criteria must be met:

The chamber must produce materiel effects similar to those that occur in natural exposure.

There must be a consistent relationship between degradation rates in the chamber and those in the field, e.g., "x" days in the chamber must be equivalent to "y" days in a particular tropic field exposure.

The ability of the chambers tested to meet the first criterion was evaluated by comparing those areas where results agreed and those where they disagreed in terms of materiel effects.

Results from the two chambers agreed with the field results in the following respects:

The digital electronic system was most insensitive to degradation in all test environments.

The optical and PHM systems were sensitive to degradation in all exposures.

In all four test environments certain components were most likely to fail, such as the operational amplifier in the optical system and the hydraulic slave cylinder in the PHM system.

In all four environments there was a systematic downward trend in PHM system performance.

Chamber results disagree with field results in the following respects:

Operational amplifier failures at the tropic open exposure site were significantly fewer than those at the tropiical greenhouse and fungus chamber exposures.

A major problem in the greenhouse was fogging of the lenses by accumulated corrosion products. Lens fogging was less severe in the other environments.

The ability of the chambers tested to meet the second criterion was evaluated by comparing performance degradation and failure rates in the four test environments:

The correlation of chambers and field results for the PHM system was fairly good. Curves of system performance versus exposure time for the PHM system in the four environments have similar shapes, and the occurrence of system failures was not significantly different among the exposures.

For the optical system, frequency of occurrence of operational amplifier failures in the chamber environment was significantly different from that in the tropic open exposure site, but was not significantly different from that in the tropic jungle site. Significant reduction in lens transmissivity during exposure was observed at the greenhouse and tropic open exposure sites, but there was no significant transmissivity reduction at the fungus chamber and tropic jungle exposure sites. These test results indicate that further refinements to the chamber methodologies are required to provide a more consistent relationship between performance and reliability degradation results in a chamber environment with those in a particular tropic field exposure environment. Because different exposure modes in the humid tropics may elicit different performance responses from materiel items (as indicated by the above results), variations to chamber methodologies may be required to simulate the various different humid tropic exposure modes.

An analysis of optical and PHM system failure occurrences and of PHM system performance showed that no meaningful acceleration of degradation occurred in the tropical greenhouse or fungus chamber. The exposure tests utilizing these chamber methodologies required exposure periods comparable to tropic jungle exposure periods to produce significant deterioration in test item performance and reliability.

SECTION 3. APPENDIXES

APPENDIX A. METHODOLOGY INVESTIGATION DIRECTIVE AND PROPOSAL

(COPY)

DEPARTMENT OF THE ARMY
HEADQUARTERS, US ARMY TEST AND EVALUATION COMMAND
ABERDEEN PROVING GROUND, MARYLAND 21005

AMSTE-ME 14 August 1975

SUBJECT: Directive, Chamber vs Environmental Deterioration Tests, TRMS No. 7-CO-RD6-TT1-001

Commander
US Army Tropic Test Center
ATTN: STETC-PD-M
Drawer 942
Fort Clayton, CZ

1. Reference TECOM Regulation 70-12, dated 1 June 1973.

2. This letter and attached STE Forms 1188 and 1189 (Incl 1) constitute a directive for the subject investigation under the TECOM Methodology Improvement Program 1U765702D625.

3. The Methodology Investigation Proposal at Inclosure 2 and the additional guidance provided at Inclosure 3 are the basis for headquarters approval of the subject investigation. Any deviation from the approved scope, procedures, and authorized cost will require approval from this headquarters prior to execution.

4. Special Instructions:

a. All reporting will be in consonance with paragraph 9 of the reference. The final report, when applicable, will be submitted to this headquarters, ATTN: AMSTE-ME, in consonance with Test Event 52, STE Form 1189.

b. Recommendations of new TOPs or revisions to existing TOPs will be included as part of the recommendation section of the final report. Final decision on the scope of the TOP effort will be made by this headquarters as part of the report approval pro[illegible]

c. The utilization of the funds provided to support the final investigation is governed by the rules of incremental funding.

AMSTE-ME 14 August 1975
SUBJECT: Directive, Chamber vs Environmental Deterioration Tests, TRMS
No. 7-CO-RD6-TT1-001

d. The addressee will determine whether any classified information is involved and will assure that proper security measures are taken when appropriate.

e. Under the new approved management concept for the methodology program, responsibilities will be delegated as follows:

(1) The Methodology Improvement Directorate will be responsible for management of the methodology programs to include: administration, funding, development, justification and documentation of the programs, and all coordination not specifically designated to other organizations and/or individuals.

(2) The headquarters technical responsibilities, which include planning, executing and controlling of specific methodology investigations, will be assigned to the most qualified individuals within TECOM using the technical sponsor concept. Although the technical sponsor concept has been approved, the details of implementation have not been finalized as yet. You will be provided with the implementation plan when it becomes available.

FOR THE COMMANDER:

/s/
SIDNEY WISE
Dir, Methodology Improvement

3 Incl
as

August 1974

1. TITLE: Chamber vs Environmental Deterioration Tests

2. INSTALLATION: US Army Tropic Test Center
P.O. Drawer 942
Fort Clayton, Canal Zone

US Army Materiel Test and Evaluation
White Sands Missile Range, NM 88002

3. PRINCIPAL INVESTIGATORS: G. F. Downs
Analysis Division
STETC-AD
AUTOVON 313-285-4170

O. H. Calderon
STEWS-TE-AE
AUTOVON 258-4515

4. BACKGROUND. US Army Tropic Test Center (USATTC) in prior test methodology efforts has recognized the paucity of knowledge on the quantitative and qualitative effects of environmental parameters of materiel deterioration. The test methodology efforts of the Data Base Tropic Research for Studies in Humid Tropics, TECOM Project No. 0-CO-059-000-001, provided the first definitive information on tropic environments. Although the finite definition of complex total environment requires decades, this work establishes a starting point, for only a few limited parameter studies had been conducted in tropic environments. The gross difference in measurement techniques and environmental types made comparisons of these studies in many cases impossible. The Determination of Optimum Tropic Storage and Exposure Sites, Phase I and II, TECOM Project No.'s 9-CO-009-000-006 and 9-CO-009-000-005, respectively, demonstrated the statistical continuity between exposure modes, e.g., open sites versus forest sites. Past material exposure studies allowed for static evaluation only of materiel deterioration, i.e., tensile strength, microbial coverage, etc. Exposure/Performance tests of Selected Materiels, TECOM Project No. 9-CO-009-000-016, demonstrated the benefits of dynamic performance tests of weathered materiel, i.e., timers and radios, in addition to static evaluation. Laboratory versus Field tests: A limited survey of Materiels Deterioration Studies, TECOM Project No. 9-CO-009-000-021, provided a literature review of previous correlation attempts. This background review revealed a general lack of success in duplicating tropical effects in chambers and laboratories.

ARMTE test methodology studies have been conducted to critically evaluate the shortcomings of the present chamber test, MIL-STD-810B, Method 508, Fungus Test. Various changes have been proposed in revising this chamber test and the technical data required for these changes are summarized in two final reports: Microbial Assimilation and Metabolic Waste Formation During Biodegradation, RDTE Project 1E665702D625, TECOM Project No. 9-CO-005-000-037. Three papers were also published in Developments for Industrial Microbiology, dealing with biodeterioration of missile components in a field environment and associated microorganisms found in the soil and air of a tropical environment.

The technical advance of material deterioration knowledge through field studies by USATTC and chamber studies by ARMTE require a joint effort to determine the feasibility of limited parameter simulation of complex natural environments.

5. STATEMENT OF THE PROBLEM. Data collected to date have progressed to the point that correlations of controlled environmental testing and natural environmental tests are warranted.

6. GOAL.

a. The investigation will result in establishing valid correlations between exposure tests in tropic and controlled environmental tests. The results of this investigation will be incorporated into a new TOP on Tropic Environmental Simulation, assuming valid correlations are found.

b. This investigation will lead to a simple, inexpensive simulation of a multivariate tropic environment.

c. The second year effort will primarily consist of verifying the initial correlation findings and attempts to accelerate environmental deterioration effects on materiel.

7. DESCRIPTION OF INVESTIGATION.

a. A joint effort between USATTC and ARMTE will be initiated to determine deterioration modes induced in natural and simulated tropic environments.

b. Both USATTC and ARMTE will:

(1) Establish a successful correlation between a natural and simulated tropic environment.

(a) Temperature, rainfall, humidity, radiation (UV, visible, IR, total radiation), salt fallout, condensation and ambient chemicals, e.g., ozone, dust, organic and inorganic particles, will be monitored.

(b) An effort will be made to monitor other natural and man-made pollutants.

(c) The greenhouse environment will be maintained to simulate, as close as possible, those factors found in a natural environment. With exception of rain, the following parameters will be reproduced: soil, simple flora and fauna, natural volatile organics, saltfall, humidity, temperature, air movement and radiation.

(2) Incorporate dynamic tests of materiel with qualitative and quantitative materiel performance measures, e.g., electrical power input and output, go-no-go criteria, use of pressure and thermal transducers, spectrophotometric measurements for optical equipment and microcalorimetry and macrocalorimetry.

(3) Choose test items that will be inexpensive yet sophisticated--exemplifying electrical, mechanical, hydraulic and optical materiel modes.

(4) Provide knowledge leading to the construction of chambers more closely simulating the natural environment.

(5) Observe and compare the test microorganisms employed in controlled environmental testing to those microorganisms associated with a natural environment.

8. JUSTIFICATION.

a. Association with mission.

(1) Both USATTC and ARMTE have the responsibility to plan, conduct and report on environmental phases of materiel test.

(2) Plan and perform scientific investigations leading to the improvement of current test methodology.

b. Present capability, limitation, improvement and impact of test if not approved.

(1) Present Capability.

(a) Well equipped laboratories at USATTC and ARMTE are available and staffed with professional personnel in the biological, chemical, metallurgical and electrical engineering disciplines. Reference Instrumentation Master Plan for USATTC and ARMTE.

(b) An environmental test chamber at WSMR, 16 feet high by 22 feet wide by 30 feet long, to be used for fungus testing, is under construction and will be available July 1974. This chamber will have the capability to cycle humidity and temperature representing any tropical environment in the world.

(2) Limitations.

(a) The controlled greenhouse facility at WSMR is not large enough to effectively perform the proposed TMD study.

(b) Instrumentation to monitor certain natural and man-made pollutants is not available.

(3) Improvements. This investigation will establish how a controlled environmental test relates to a tropic test. These comparisons will emphasize the scope and limitations of controlled environmental testing. This information will allow test personnel to employ the controlled environmental data to estimate the deterioration of similar equipment exposed to tropic environments.

(4) Impact. In terms of most of the significant dimensions of the military materiel acquisition cycle--time, cost, convenience and precision--

Chamber vs Envrionmental Deterioration Tests (cont)

chamber tests are highly preferable to natural field tropic tests. In terms of risk, laboratory and chamber test technology is not sufficiently advanced or predictive to replace natural tests in the field. A successful conclusion to this study would represent a major technological breakthrough and result in substantial dollar savings if tropic surveillance testing could be performed in CONUS. An indication of the magnitude of the surveillance test effort is that USATTC presently has 25,950 pounds of bulk chemicals and explosives, 1,095 missiles and rockets, 44,060 rounds of ammunition, 189 demolition charges, 5,170 feet detonation cord, 240 mortars, 976 grenades (CS and Smoke) and 20 naval weapons.

c. Dollar Savings. Not predictable, but would represent considerable savings to Department of the Army (DA) if tropic surveillance testing could be reliably and inexpensively performed in CONUS on an accelerated basis.

d. Workload.

(1) Over the past 5 years USATTC has experienced 35 tropic exposure tests of Army materiel. The anticipated future workload will be approximately seven tests per year. Examples of items for testing are:

FY	75	76
Stinger ADS		DTII
Night-Vision Sight/Crew Served Weapons	DTII	

(2) Over the past 6 years, the Climatic Branch (WSMR) has performed 105 MIL-STD-810B, Method 508, fungus resistance tests. The anticipated future workload will require approximately 18 fungus tests per year. Examples of items anticipated for testing are:

FY	76	77	78
AN/TSQ-73	DTIII		
Stinger	DTII	DTII	DTIII
SAM-D	DTII		DTII

e. Association with Requirements Documents.

(1) MIL-STD-810B, Environmental Test Methods, 15 June 1967.

(2) MTP-5-2-584, Microbial Resistance Tests, WSMR, 6 June 1968.

(3) AR 70-38, Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions, 1 July 1969.

f. Others. NA

9. RESOURCES.

a. Financial.

	In-House ARMTE	In-House USATTC	Out-of-House ARMTE	Out-of-House USATTC
	Dollars (Thousands) FY76			
Personnel Compensation	24.0	13.8		
Travel	0.8	1.0		
Contractual Support			33.5	7.0
Consultant and Other Services	0.0	0.0		
Materials and Supplies	0.5	0.5		
Equipment	1.0	1.0		
G&A Cost		13.8		
Subtotals	26.3	30.1	33.5	7.0
FY Totals		59.8 ARMTE		37.1 USATTC

b. Explanation of Cost Categories.

(1) Personnel Compensation. This represents compensation chargeable to the investigation for utilizing technical or other civilian personnel assigned to the investigation.

(2) Travel. NA

(3) Contractual Support. USATTC contract personnel will be used during the field exposure phase, for emplacement, collection and processing of exposed samples. The reduction and evaluation of data collected will be accomplished entirely by the Test Analysis Branch professional personnel. Because of the limited number of personnel in ARMTE and the fluctuating workload, graduate students at New Mexico State University and/or the University of Texas at El Paso will be contracted to assist in this investigation by performing detailed, time-consuming laboratory analysis. Cost and time schedules are summarized in paragraphs 9a and 10, respectively.

(4) Consultants or Other Services. NA

(5) Materials and Supplies. NA

Chamber vs Environmental Deterioration Tests (cont)

(6) Equipment. NA

(7) G&A Cost. USATTC; Host Tenant Support, ARMTE; None

c. Obligation Plan.

	FQ	1	2	3	4	Total
Obligation Rate (Thousands)	USATTC	11.5	18.5	3.9	3.4	37.1
	ARMTE	7.8	39.5	6.5	6.0	59.8

d. In-House Personnel.

USATTC	Man-Hours Number Required	FY76 Available	Total Required
Biologist GS-0401	575	575	575
Electronics Eng GS-0855	235	235	235
Chemist GS-1320	170	170	170
Materials Eng GS-0806	170	170	170
	1,150	1,150	1,150

ARMTE	Man-Hours Number Required	FY76 Available	Total Required
Microbiologist GS-0403	575	575	575
Elec Engineer GS-0855	520	520	520
Mechanic GS-0802	885	885	885
	1,980	1,980	1,980

Chamber vs Environmental Deterioration Tests (cont)

10. INVESTIGATION SCHEDULE.

USATTC	FY76 J	A	S	O	N	D	J	F	M	A	M	J
In-House	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	R
Contract	X	X	X	X	X	X	X	X	X	X	X	X

Symbols: ----- Active investigation work (all categories)

X X X Contract monitoring (in-house only)

A Award of Contract

R Final Report due to HQ, TECOM

ARMTE	FY76 J	A	S	O	N	D	J	F	M	A	M	J
In-House	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	R
Contract	X	X	X	X	X	X	X	X	X	X	X	X

Symbols: ----- Active investigation work (all categories)

X X X Contract monitoring (in-house only)

A Award of Contract

R Final report due to HQ, TECOM

11. ASSOCIATION WITH TOP PROGRAM. The results of this investigation, if definitive, will be incorporated into a TOP on Tropic Environmental simulation. Material Test Procedure 5-2-584, Microbial Resistance Test will be revised as appropriate. Recommendations will be made to update MIL-STD-810B, Method 508, Procedure I.

(END COPY)

APPENDIX B. DATA COLLECTION PROCEDURES

OPTICAL AND DIGITAL ELECTRONIC SYSTEMS

The following text provides detailed instructions for evaluating performance of exposed test articles. All data will be recorded on the attached form.

1. Connect laboratory power supplies observing proper polarities and voltages. System is common ground. Wiring on the tester is labeled.

2. Set unit to be tested on stand to keep three screws on bottom box from touching work table.

3. Securely connect six-conductor mating plug to receptacle.

4. Open box cover and connect test lead of tester (red insulation) to TP1 on circuit board.

5. Apply 20 VDC ± .02v with the unregulated power supply monitoring voltage at test point "UN-REG-IN."

6. Record test item regulate voltage at test point TP1.

7. Decrease unregulated voltage to 15 VDC ± .02v, and record regulated voltage.

8. Next, reduce voltage to 12 VDC ± .02v, and record.

9. Then to 7.5 VDC, ± .02v, and record.

10. Set frequency range switch to position A, adjust frequency to 100 hertz ± 5 hertz. Monitor frequency with counter connected to "FREQ" on tester.

   a. Clear both counters with reset buttons on tester and test article.

   b. Push count button--record data displayed on both units.

   c. Reset both units and again count.

   d. Repeat a through c five times.

11. Set range switch to position B, adjust to 1 kilohertz ± 10 hertz. Repeat steps 10a through 10c five times at this frequency.

12. Set range switch to C, adjust to 10 kilohertz ± 100 hertz. Repeat steps 10a through 10c five times at this frequency.

13. Set switch to D, adjust to 100 kilohertz ± 500 hertz. Repeat steps 10a through 10c five times at this frequency.

14. Switch to E, adjust to 500 kilohertz ± 1 kilohertz. Repeat steps 10a through 10c five times at this frequency.

15. With switch still in position E, adjust to 1 megahertz ± 10 kilohertz. Repeat steps 10a through 10c five times at this frequency.

16. Connect test lead of tester (black insulation) to TP2 on exposure apparatus.

17. Set light shield (PVC tubing) longitudinally along optical assembly and over photocell. (When properly set, sheet metal screw under photocell will fit small hole in end of light shield.)

18. Close cover with TP2 connected and wire routed through access hole on left hand side of hinged cover.

19. Cover box with black cloth to exclude ambient light.

20. Verify voltages with the DVM at their respective test points on the tester, and adjust lab supplies as necessary.

Positive for Optics:	+ 12 VDC	± 10 mv
Negative for Optics:	- 12 VDC	± 10 mv
"Unreg In":	+7.5 VDC	± 20 mv

Note: When adjusting and/or setting voltages, be sure no segment of the counter numeral display (TL-302) is lit.

21. Record the following for Optics Test, "LED ON": amplifier input voltage at TP2, regulated voltage at TP1 and amplifier output voltage at "Optics Out."

22. Remove cloth, open box and set light filter snugly against light shield, arrow towards shield. Close box, cover with cloth, then verify optics voltages following procedure in step 20.

23. Measure the three voltages per step 21 and record on line labeled "10% Fltr," for Optics Test.

24. With cloth still on box and voltmeter at TP2, depress the reset switch on the top of the test item. This turns off the LED in the optics system. Hold the switch down until the voltage at TP2 stabilizes (30-120 seconds).

25. Measure the three voltages per step 21 and record on line labeled "LED OFF" for Optics Test.

26. Open box, remove light shield and filter.

27. Carefully set <u>TEST LED</u> over photocell of unit being tested. Route cable through indent in front of cover. Close box and cover with cloth.

28. Verify voltages following procedure in step 20.

29. Measure the three voltages per step 21 and record on line labeled "TESTER LED," Optics Test.

30. Move DVM lead to "PHOTOCELL OUT" and set DVM to measure resistance.

31. Set range switch to A and adjust the frequency to 132 hertz.

32. Clear the counter with the reset switch and press the count button once to get a display of "11." If the count is off, reset the counter and readjust the frequency until an "11" count is obtained.

33. Place the tester photocell over each digit and measure the photocell resistance. Record the resistance readings for the unit and ten digit on line labeled "Display 1," Seven-Segment Readout.

34. Press the count button seven more times to obtain a display of "88."

35. Repeat step 33 and record readings on line labeled "Display 8," Seven-Segment Readout.

36. Turn off the power supplies and disconnect all cables and test equipment from the test item.

37. Return the test item to its environment.

38. Note any system malfunctions and events which might influence test results. Report all incidents to the project officer immediately after returning from the field.

DATA COLLECTION FORM
OPTICAL AND DIGITAL ELECTRONIC SYSTEMS

SN____________ LOC____________ DATE____________

START__________ STOP__________

TEMP____________ RH____________ TEST ITEM TEMP____________

OPERATOR____________ ALL VOLTAGE READINGS (V ± .000)

1. INPUT V	REG OUT	TP 1	TP 2	2. COUNTER 5 SAMPLES	TESTER READINGS	AMOUNT TEST ITEM RDGS OFF
20V				100 hz		
15V				1 khz		
12V				10 khz		
7.5V				100 khz		
				1 Mhz		

3. OPTICS TEST	OPT OUT	TP 1	TP 2	TSTR LED V
LED ON				
10% Fltr				
LED OFF				
TESTER LED				

4. SEVEN-SEGMENT READOUT (Kohm ± .001)

	Units Digit	Tens Digit
Display 1		
Display 8		

NOTES:

PNEUMATIC/HYDRAULIC/MECHANICAL SYSTEM (PHM)

a. Description: The pneumatic/hydraulic/mechanical test device consisted of a pneumatic diaphragm unit which was pressurized to activate a master cylinder which then activated a slave cylinder. Measurements were taken of the amount of movement of the slave cylinder's internal element versus the amount of air pressure applied to the diaphragm. Specifically, the units were tested by applying 25 psig and measuring the movement of the slave. Then the unit was pressurized to 40 psig and the amount of movement measured. Finally, the unit was depressurized to 25 psig and the amount of movement measured. By using two pressures and cycling from low to high and back to low, three data points were developed which indicated changes that occurred with each unit.

b. Detailed Test Procedure: The testing apparatus used two pressure regulators to break down the air pressure to 25 and 40 psig. The reduced pressures were fed to two control valves which were closed. Being sure that the pressure release valve was closed, the low pressure control valve was opened and the two pressure gauges were checked to assure that 25 psig was achieved. Then, using a depth measuring micrometer, the amount of movement or deflection of the threaded steel bar coming out of the front of the slave cylinder was measured to the closest thousandth of an inch. The measurement was recorded in the log book. After completing this measurement, the low pressure control valve was closed and the high pressure control valve opened and the pressure gauges were checked to assure that 40 psig was achieved. The same measurement which was done at the lower pressure was taken and recorded. The next step was highly important; the high pressure control valve was closed and the low pressure control valve opened, then the pressure release valve was carefully opened to slowly bleed the air pressure down to 25 psig before the pressure release valve was closed. The amount of the rod movement was measured a third time and recorded. The unit was depressurized by closing all pressure control valves and bleeding off the pressure using the pressure release valve. The test item was returned to the environment.

c. In order to preserve the measuring elements of the test device, a small amount of silicon grease was applied to the rod end of the slave cylinder piston and the adjacent steel plate.

APPENDIX C. DATA

Table C-1. Optical System Failures--Jungle Site

Exposure Time (weeks)	Unit (SN)	Component
23	27	Resistor
27	44	Operational Amplifier
27	54	Operational Amplifier
29	27	Operational Amplifier
34	40	Operational Amplifier
38	44	Operational Amplifier
44	44	LED

Summary:
- 5 operational amplifier failures
- 1 LED failure
- 1 resistor failure
- 7 Total component failures

Table C-2. Optical System Failures--Open Site

Exposure Time (weeks)	Unit (SN)	Component
16	13	Operational Amplifier
21	30	LED
21	25	Voltage Regulator
27	30	LED
46	23	LED
48	30	LED

Summary:
- 4 LED failures
- 1 operational amplifier failure
- 1 voltage regulator failure
- 6 Total component failures

Table C-3. Optical System Failures--Tropical Greenhouse

Exposure Time (weeks)	Unit (SN)	Component
17	32	Operational Amplifier
17	32	Resistor
22	55	Operational Amplifier
24	39	LED
34	41	LED
34	59	Operational Amplifier
38	39	LED
38	28	LED
38	[illegible]	Operational Amplifier
40	46	Operational Amplifier
42	59	LED
44	31	Operational Amplifier
45	55	Operational Amplifier
47	6	LED
50	46	LED
50	53	Operational Amplifier

Summary:

8	operational amplifier failures
7	LED failures
1	resistor failure
16	Total component failures

Table C-4. Optical System Failures--Fungus Chamber

Exposure Time (weeks)	Unit (SN)	Component
17	17	Resistor
42	17	Operational Amplifier
44	48	Operational Amplifier
50	14	Operational Amplifier

Summary:

3	operational amplifier failures
1	resistor failure
4	Total component failures

Table C-5. PHM System Failures

Exposure Time (weeks)	Unit (SN)	Exposure
27	T-11	Open
27	T-15	Open
28	W-22	Greenhouse
32	W-24	Greenhouse
33	T-8	Jungle
33	T-10	Jungle
33	T-17	Open
33	T-18	Open
33	T-23	Open
34	W-6	Greenhouse
34	W-15	Greenhouse
34	W-18	Greenhouse
34	W-30	Greenhouse
35	T-26	Open
35	T-30	Open

Table C-6. Optical System Failure Rates

Exposure	No. of Failures	Exposure Time (x1,000 hrs)	No. of Exposure Items	Total Exposure Time (x1,000 hrs)	Failure Rate (failures/1,000 exposure hrs)
Jungle Site	7	8.736	5	43.68	0.160
Open Site	6	8.736	20	174.72	0.034
Tropical Greenhouse	16	8.736	15	131.04	0.122
Fungus Chamber	4	8.736	5	43.68	0.092

Table C-7. PHM System Failure Rates

Exposure	No. of Failures	Exposure Time (x1,000 hrs)	No. of Exposure Items	Total Exposure Time (x1,000 hrs)	Failure Rate (failures/1,000 exposure hrs)
Jungle Site	2	5.88	5	29.4	0.068
Open Site	7	5.88	20	117.6	0.060
Tropical Greenhouse	6	5.71	20	114.2	0.053
Fungus Chamber	0	5.71	5	28.6	0.000

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Chamber vs Environmental Deterioration Tests
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